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CONTENTS

PAPERS AND PROCEEDINGS OF ANNUAL MEETING—PART I PAGE

A World-Wide Cooperative Program on Insect Resistance to Insecticides.....J. W. Wright 137
Present Status and Future Possibilities of Biological Control of Mosquitoes.....B. V. Travis 143
The Relation of Insect Taxonomy to Mosquito Control.....P. W. Oman 147
Report of Mosquito Control in Virginia.....R. E. Dorer 151
Mosquito Control Work in Maryland.....G. S. Langford 153
Mosquito Control Highlights from New Jersey.....L. W. Campbell 154
Mosquito Control Notes from Pennsylvania.....R. W. Gies 156
Mosquito Control in New York State in 1956.....C. T. Williamson 156
Mosquito Control in Rhode Island, 1956–57.....J. F. Pannone 159
Summary Report on Mosquito Control in Canada.....C. R. Twinn 160
Report on Mosquito Control in the State of Ohio.....P. B. Brockway, Jr. 161
Mosquito Control in Illinois.....W. J. Buchanan 161
Report of the Utah Mosquito Abatement Association 1957.....T. A. Schoenfeld 163
Past and Present Mosquito Control in California.....H. R. Greenfield and G. E. Washburn 164
Importance of Organic Phosphorus Insecticides in Mosquito Control in California..A. F. Geib 166
Laboratory Study of the Release of Some Organic Phosphorus Insecticides into Water from Granular Formulations.....D. E. Weidhaas 168
Studies with Organophosphorus Compounds in the Control of *Psorophora* Larvae in Mississippi Rice Fields.....W. Mathis and H. F. Schoof 173
Field Tests with Four Phosphorus Insecticides Against Salt-Marsh Mosquitoes in Florida.... A. N. Davis and J. B. Gahan 180
Aerial Spray with Malathion, Pyrethrum, and Allethrin Against *Aedes taeniorhynchus* in Florida.....A. N. Davis, E. J. Beidler and J. D. Ringdahl 184
Progress Report of an Investigation of the Relationship of Water Table Level Fluctuation to Mosquito Development and Population Density, 1954–1956..... F. R. Du Chanois and L. B. Alltop 186
A Progress Report on Dosage Tests with Mosquito Adulticides..... A. J. Rogers, E. J. Beidler and C. B. Rathburn, Jr. 190

(Continued on Page XX)

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PAPERS AND PROCEEDINGS OF THE 13th ANNUAL MEETING

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PART I

A WORLD WIDE COOPERATIVE PROGRAM ON INSECT RESISTANCE TO INSECTICIDES

J. W. WRIGHT *

The majority of persons concerned with public health today are no doubt aware of the existence of WHO, know it to be a specialized agency of the United Nations and realize that it has certain international responsibilities. However, it is unlikely that the aims and objectives of the Organization and the ways in which these are achieved are as widely understood. I propose therefore to outline and discuss one facet of its program, hoping that this will not only be of interest to those concerned with insect control, but that it will also provide some indication of how the solution to a problem common to all countries might be found through international collaboration.

WHO's fundamental goal is the attainment by all peoples of the highest possible level of health and one of its main functions is to act as a directing and co-ordinating authority in international health matters. Its membership now includes almost every country of the world and its interests extend into all branches of public health.

It is natural therefore that it should have a special interest in the control of diseases of man transmitted by insects and that work on this subject should always be given an important place in its programs. During the past ten years, emphasis has been placed on the development of large-scale vector-borne disease control projects and for the most part these have been remarkably successful.

For example, serious outbreaks of typhus fever are now rare; plague is being controlled where epidemics were once regular events; in some areas leishmaniasis and onchocerciasis have almost disappeared; hundreds of millions of people are being protected from malaria and the world-wide eradication of the disease is now considered to be technically possible.

These gains are of course due almost entirely to the high degree of efficiency of the residual insecticides. Since World War II their use in public health programs has increased steadily until the stage has been reached where almost complete reliance is being placed upon them for the control of the majority of vector-borne diseases. Insecticides-resistance has, as a result, particular significance and it is generally accepted that this phenomenon is the most important problem confronting public health authorities at the moment.

The situation is aggravated by the fact that impressive social and economic gains have resulted from the large-scale application of insecticides and further advance rests to a large extent on the ability of health authorities to maintain and extend

* Division of Environmental Sanitation, WHO, Geneva.

their control over insect vectors of disease.

However, because of the emergence of resistance this has become severely diminished in many parts of the world and the welfare of millions of persons now depends on a solution to the problem.

Let us consider for a moment the present status of physiological resistance from a health viewpoint.

The number of proved cases has increased steadily since 1946, when resistance in house flies was reported from Sweden, and there is now evidence to show that at least ten species of insects are affected.

The house fly is now almost universally resistant to the chlorinated hydrocarbon insecticides. In addition, it has been reported that effective control of this insect can no longer be achieved with the organophosphorus compounds in Denmark and Florida in the U. S. A.

Physiological resistance has been proved to exist locally in at least five species of anophelines; namely, *A. sundiacus* in Indonesia and *A. stephensi* in Saudi Arabia, both to DDT; *A. gambiae* in Northern Nigeria and *A. quadrimaculatus* in Mississippi, U. S. A., to dieldrin; and *A. sacharovi* in Greece to both groups of insecticides.

WHO recently undertook a survey of the susceptibility of body lice to insecticides throughout the world. The results of this survey reveal that whereas susceptibility of lice to pyrethrins appears to be almost universal, significant resistance to DDT exists in many parts of the world and that there are several indications of resistance to BHC.

In *Aedes aegypti* two instances of resistance have been recorded. The first one is by the Director of the Pan-American Sanitary Bureau, who in his 1955 report states that "since the fourth cycle of DDT treatment in 1953 in Ciudad Trujillo, Dominican Republic, the *A. aegypti* index has been generally rising despite continuation of spraying cycles. It is concluded that this species has developed resistance to DDT." The second emanates from Trinidad, where concentrations of up to 1 p.p.m. of DDT gave no certainty of kill. Laboratory examination of larvae from the island showed a high degree of resistance. In addition, reports of resistance have been made in other areas of Latin America, but up to now these have not been published with the necessary supporting quantitative data.

Culex fatigans has been known for many years to possess a high degree of natural resistance to DDT which is often increased by exposure to residual insecticides. However, reports reveal that other species have become resistant to the chlorinated hydrocarbons, including *C. tarsalis* in California and *C. molestus* in Italy.

In addition, evidence of a conclusive character has been published showing that resistance exists in 12 species of insect vectors of minor or potential danger to man and that in 15 species resistance has been indicated but not proved.

There is every indication that the problem is outgrowing our ability to deal with it. Resistance to the chlorinated hydrocarbon insecticides has been known to exist for at least 10 years, but in that time we have not developed measures to prevent it. At the advent of DDT man's knowledge of biology was insufficient to permit him to grapple adequately with the problems that have resulted from its widespread use, and the use of similar chemicals; furthermore, insufficient scientific progress has been made since then. For example, our knowledge is imperfect now, as it was then, regarding the exact mode of action of the chlorinated hydrocarbon insecticides, and after almost a decade of experience we are still unable to describe with accuracy the causes of resistance.

It is reasonable to expect that having been presented with a means of vector control unparalleled in efficiency, man would have made every effort to retain its effectiveness by ensuring that an amount of research commensurate with its value and the extent of its use would be carried out. However, it does not appear that this has occurred.

During 1955 and 1956 WHO undertook a world-wide study to ascertain the extent of research being carried out on insect resistance and the potentialities for expanding research on this subject. One hundred twenty-four laboratories in 49 countries known or believed to be engaged in resistance research were approached. These were distributed as follows:

	Countries	Laboratories
Africa: South of the Sahara	11	20
America: North	3	33
America: Central and South	14	20
East Mediterranean	4	9
Europe	7	17
South-East Asia	1	2
Western Pacific	9	23

For the purposes of the study "research on resistance" was divided into two main groups. The first related to laboratory experimentation and the second to the field work. The former embraced biochemistry, genetics, physiology, morphology, biology and insecticide evaluation, while in the latter were included evaluation of insecticides, behavior, detection and biology.

It was found that in 47, or 38 percent, of the laboratories no research of any type on resistance was being performed. Fourteen of these (out of a total of 20) were in Africa; 14 (out of 20) in Central and South America; 2 (out of 9) in the East Mediterranean region; 3 (out of 17) in Europe; and 14 (out of 23) in the Western Pacific.

Sixty-six (53 percent) were engaged in laboratory research, although 15 were concerned with the evaluation of insecticides only.

This means that throughout the world no more than 51 laboratories are working on problems fundamental to the solution of resistance. Their location is interesting:

Two are in Africa: one in East Africa and one in West Africa.

North America has 27: 3 in Canada, 24 in the United States.

Two are situated in South America: one in Venezuela, one in Brazil.

Two are in the East Mediterranean region.

Europe has 11: one in Denmark, two in Germany, two in Italy, two in the Netherlands, one in Switzerland and three in the United Kingdom.

Western Pacific has 7: two in Australia, three in Japan, one in New Zealand and one in Malaya.

Thus the bulk of fundamental research on resistance is being performed in the U. S. A., Western Europe and Japan. Almost no work is being done in regions where insect-borne diseases are particularly important.

Only 41, or 32 percent, of the 124 laboratories were found to be performing field research. Twenty-one of these were concerned exclusively with the detection of resistance and 7 were working solely on the evaluation of insecticides. Five laboratories exclusive of these 28 were carrying out work on both subjects. This leaves only 8 institutions with what might be defined as a balanced program of field research on resistance. Of these, one was in Africa, three in North America, one in South America, one in the East Mediterranean, one in Europe and one in South East Asia.

The deficiency in field research on resistance is thus self evident. Services of this type should be an essential and integral part of every large-scale operating program, particularly as far as ecological and behavioral studies are concerned. Concentrated efforts on these lines could play a vital role in developing better and more economical programs and in delaying the onset of resistance where this is known to be potentially a problem.

A number of additional factors emerged from the study, affecting the quality and the quantity of research, which are not apparent from the statistics quoted above.

Much of the work being done, both in the laboratory and the field, is on a part-time basis. This is mainly due to inadequacy of funds and shortages in well-trained scientific and technical staff as related to the variety and breadth of problems requiring attention. The almost universal lack of money is reflected in a need for suitable equipment and physical necessities, such as rooms with temperature and humidity controls. In many countries research has only recently been started and

some time must still elapse before the first results will appear.

The importance of a better exchange of information between workers in the same and allied fields is stressed by scientists in almost every part of the world, particularly those in remote areas. This is related not only to published material but also to data which might not necessarily reach the technical press. There is also a widely-held belief that if some system could be evolved whereby advance information on articles awaiting publication could be made generally known, overlapping and waste would be avoided.

Many persons are of the opinion that publication channels as they exist today are inadequate for a rapid dissemination of scientific data, periods of up to 18 months often elapsing between the termination of a research project and the publication of the results.

All these facts were considered by an expert committee of WHO convened in July 1956 to advise the Director-General on the problem of resistance. This group concluded that "considering the magnitude and importance of operational programs for the control of insect vectors of disease, the proportion of funds devoted to research on the resistance problem is entirely inadequate and out of line with sound economic practice." As far as existing research is concerned, the lack of liaison and the inadequate exchange of information between workers could only give rise to "duplication of effort, increased costs and lowered efficiency."

On the basis of these findings the committee made a proposal with far-reaching implications. It recommended that a greatly accelerated effort be made on resistance research based upon world-wide scientific collaboration, with WHO assuming leadership for the co-ordination and stimulation of work on all aspects of the problem.

It is appreciated that "co-ordination" gives rise to different concepts in different individuals. To some it is synonymous with regimentation—a condition to be firmly resisted. To others it conjures up visions of something akin to organized plagiarism. Yet in modern public health it is far removed from either. Instead, it can and does mean a voluntary collaborative effort by scientists and field workers throughout the world to solve a problem common to mankind as a whole. There is little doubt that resistance justifies an approach of this nature. It appears unlikely, in the light of existing knowledge, that any one discovery will provide a complete solution to the problem. It is more probable that by piecing together the results of work performed by workers in different parts of the world a pattern will emerge from which it will be possible to draw certain conclusions.

But how is this to be achieved? How can the pieces be brought together and put into proper perspective?

The Director-General of WHO, who has referred to modern medical science as a "synthesis of all the disciplines that have as their ultimate aim the health of man," has written in his Report for 1956 of the role WHO might play in attaining this objective. He considers the "task of promoting the free exchange of information among research workers in the many branches of public health" to be a fundamental responsibility of the Organization. As far as international co-ordination of research is concerned, he states: "This aspect of the programs undertaken by WHO is related to one basic function of the Organization, which is to pool all available scientific and technical knowledge, constantly to appraise it, and to study its applicability to the solution of public health problems."

In line with this policy and with the authority of its governing bodies, WHO has initiated a program with the following general objectives:

1. *The collection and dissemination of information.* The Organization is acting as a depository for information on resistance from all sources and is distributing it to workers throughout the world. This service is still in its infancy and at present is related almost completely to

published material. However, there is an increasing amount of advance information becoming available and an extension of this is being encouraged. Up to now six information circulars have been distributed to research workers and contact has been made with almost 300 scientists in different parts of the world. As this two-way flow of information increases in volume, it is believed that all involved in the resistance problem will benefit.

2. *The stimulation of new research.* WHO's financial resources are too meagre to permit it to do anything but stimulate existing research institutes to do work in practical fields of international importance. The final decision for the allocation of funds for research must of necessity continue to rest with the national administrations or other authorities controlling the finances of laboratories. However, the Organization can and does provide small grants to laboratories with adequate leadership to assist in the procurement of equipment and in engaging technical personnel. It has been found that this type of support often has a catalytic effect on a total research program far in excess of the amount of money involved and at very much less cost than the value to the country concerned.

Financial support of an amount that will make an impression of substance to the research problem will continue to emanate from national governments, industrial bodies, universities, and, in particular, from the fund-granting foundations and agencies. WHO, through its contacts in different parts of the world, is in a favorable position to advise these bodies on the subjects in which the investment of funds might provide the greatest benefit.

3. *The co-ordination of existing research.* The Organization, through its staff and consultants, is building up a liaison system between laboratories designed to bring workers with common interests into personal relationship, with the aim of avoiding duplication and overlapping of effort.

4. *The procurement and training of professional and technical staff.* The fellowships program of WHO is being used to train both professional and technical staff. Governments may request assistance for key professional personnel to obtain advanced training. In addition, assistance is being given to national training programs for technical and auxiliary staff.

It is also planned that WHO should sponsor training seminars or symposia to which scientists actually working on research projects would be invited.

The exchange of scientific workers between different countries is another procedure which in specific circumstances is meeting an important need.

5. *The development of standard tests for determining resistance.* Accurate information on the pre-operational level of susceptibility of insect populations is an essential prerequisite to any program in which chemical control is contemplated. This permits an early definition of potentially dangerous areas to be made and provides a basis for comparison when the first signs of resistance appear. In addition, it is important that routine tests be performed throughout the course of a program to ascertain at an early stage any change in the susceptibility level.

The Busvine/Nash method has for a number of years been a means of providing such data on adult mosquitoes. Some of the data obtained with it have recently been assembled and published. In collaboration with the Expert Advisory Panel on Insecticides of WHO, a standard test method has been developed based upon this technique, and it is at present under trial in different parts of the world. This will provide an accurate and simple means of assessing susceptibility levels that will not only be comparable with earlier figures obtained with the Busvine/Nash method, but which permit comparison between resistance levels of the same species in different areas of the world.

Development of a standard test method for mosquito larvae is also well advanced

and this method will shortly be put into general use. The importance of this, particularly in respect to *Aëdes aegypti,* cannot be over-emphasized and it is hoped that it will be instrumental in bringing about clarity in areas where there is none at present.

Reference has already been made to the survey carried out between 1953 and 1956 on the susceptibility of lice. In this survey, a test method was used which was proposed originally by the U. S. Department of Agriculture laboratories in Orlando, Florida, to the Associate Committee on Insect and Rodent Control of the U. S. Forces. Although this technique is known to be prone to certain variables, its use as an accurate screening medium has been proved. It has recently been revised and is being adopted as an integral part of typhus control programs all over the world.

Test methods for determining the susceptibility of other insects of medical importance, such as flies and fleas, are also under study and will, it is anticipated, become available shortly.

6. *The procurement and testing of new insecticides.* It is important that new insecticides (or their formulations) be evaluated and put through field trials as soon as possible, so that their use on a wide scale is not delayed.

Work on the sorption of insecticides by mud walls is an example of this. In certain parts of the world, particularly Africa and Mexico, this phenomenon is a major problem, with the insecticide deposits on sprayed mud surfaces becoming ineffective in a matter of days. Collaborative work on formulations with anti-sorptive properties has made good progress and the Organization is at present sponsoring field trials with one of them in both Africa and Latin America.

7. *The sponsoring of meetings of scientists engaged in resistance research.* A meeting of the Expert Committee on Insecticides of WHO was held in 1956 and another is planned for this year. In July a group will be convened to study ways and means of bringing about effective coordination between individual national laboratories and between the laboratory and the field. Through these experts advice is obtained on all aspects of the resistance problem, together with an assurance that whatever form the Organization's program takes, it will be on realistic and scientific lines.

It is appreciated that a program of this type has many limitations. WHO does not play an executive role at the national level and can do no more than advise, coordinate and stimulate action. If the problem of resistance is to be solved, true international collaboration is essential: national governments to support more work, fund-granting agencies to provide the means to expand research where finances are limited. Above all, unrestrained collaboration between the scientific workers themselves is vital to the success of any scheme, whether proposed by WHO or any other body.

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PRESENT STATUS AND FUTURE POSSIBILITIES OF BIOLOGICAL CONTROL OF MOSQUITOES

B. V. TRAVIS
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It is indeed unfortunate that so many investigators deserted the field of biology when extremely effective insecticides were developed beginning about 1945. For some strange reason the idea arose almost universally among entomologists that insecticides such as DDT, benzene hexachloride and others were so very effective in the control of insects that it was unnecessary to be concerned in any way with the biology of the insects.

Some of this attitude came into being in the 1920's when paris green was found to be so effective against anopheline mosquitoes. The literature contains thousands of references prior to 1945 dealing with all kinds of naturalistic or biological control of mosquitoes (Bates, 1949; Boyd, 1949). Yet today one not only finds a rather minimum utilization of these control measures but likewise the literature pertaining to the biological control of mosquitoes has almost completely disappeared from our scientific journals.

For the purpose of this discussion, it will be necessary to exclude reference to chemical control for the direct control of mosquito larvae and adults. Likewise it will be necessary to exclude discussion on the use of indirect control for mosquitoes such as the alterations of environmental conditions by the use of herbicides; and the use of water management as related to the removal of water either by drainage or by fills. Papers on these subjects are filling our literature today and certainly everyone is aware of their possibilities. Therefore, there is no need to do more than refer to them. If all such items are excluded what is left to discuss? There are left at least three main topics: (1) environmental control, (2) predators and (3) parasites.

ENVIRONMENTAL CONTROL. Environmental control here will include only such procedures as fluctuating water levels, making use of wave action, altering the chemical composition of water and the utilization of plants. All of these procedures have been used in the past to limit the size of mosquito populations and some are being used at least in a minor way today.

Fluctuating Water Levels.—The best example of water level fluctuation is the program of *Anopheles* mosquito control used by the T.V.A. in their water impoundments. Certainly everyone must be aware of their method of controlling the water level of the artificial lakes with the outlet gates on the impoundment dams. Perhaps the main benefit of the fluctuation is that the shore-line debris can be stranded on the shore. Also the water line can be lowered below the line of emergent shoreline vegetation. Without the protection of the debris and the emergent vegetation the larvae cannot survive.

Wave Action.—The failure of the larvae to survive in the T.V.A. water impoundments is to a large part due to the inability of the larvae to withstand wave action. Wave action breaks the contact of the larvae with the air so frequently that the larvae drown.

In many communities the shore lines of the lakes and ponds are carefully prepared to discourage emergent vegetation, thus exposing the mosquito larvae to wave action. In Orlando, Florida, for instance where there are more than 30 lakes within the city limits, few mosquitoes are produced largely because of the clean shore lines.

Locally, here and there throughout the world, use is made of wave action either by clean shore lines or by arranging drain pipes into ponds so the outlet end is several feet above the water level of the pond. The water then falls on the surface of the pond instead of flowing in more gently along the shore. The falling water creates wave action that prevents mosquito production.

Altering Chemical Composition of Water.—It is well known that some species of mosquitoes cannot tolerate salt water. On the other hand, other mosquitoes do not consistently produce large numbers if the salt is absent. The principal group where the manipulation of the salinities has given considerable control has been in the anophelines. There have been limited areas where it has been possible to open up freshwater lagoons or marshes to tidal waters. As the salinities of the water in these marshes and lagoons became greater the mosquito species that could tolerate the salt were gradually excluded. Granted of course that it was common for species that tolerate salt to move into the same areas and to produce undesirable numbers of mosquitoes, what has happened is that the species that have moved in are not as important in the transmission of malaria as the species that have been excluded. Therefore, even though the total number of mosquitoes is not lowered, the disease problem has been reduced.

Here and there in the literature one finds another water manipulation method for the control of mosquitoes. This is the pollution of water, particularly in small ponds and small marshy spots. The pollutions render the environment unfavorable for the producing of the anopheline species. Here again most of the attention has been directed at the control of malaria-bearing mosquitoes. As is well known, many mosquito species favor polluted waters for development, and enormous populations can result. The pollution has been created mostly by dumping into the water various plant materials such as grasses, logs and leaves. Such pollutions are not particularly undesirable from a public health point-of-view. Naturally, pollutions with garbage and sewage that might create health hazards would not be desirable.

Utilization of Plants.—The utilization of plants to control mosquitoes is somewhat limited, but if one has the situation that fits the control procedure it is quite satisfactory.

It has been well known for many years that some species of *Anopheles* prefer water that is well exposed to sunshine. This is particularly true for species whose larvae occur along the margins of slow moving streams. Good control of these species has been effected by encouraging the natural growth of plants, or by planting shrubs and trees to shade the margins of the streams. Shading in this way makes the environment unsatisfactory for mosquito larvae, thereby reducing the production of mosquitoes.

Some mosquito adults prefer either shade or sun, and there are more shade-loving that sun-loving species. This means, as shade is increased, the mosquito population is increased. The increase of shade does not increase the mosquito production, but does improve the harboring places. The shrubbery around the home thus gives mosquitoes protection from the wind and may increase the local mosquito problem. This problem can be alleviated by trimming the shrubbery high to allow air circulation and likewise by not plant-

ing the thick low growing types of shrubbery.

Some aquatic plants control production of mosquitoes by covering water surface so completely that there is not enough surface to accommodate large populations of mosquitoes. Plants such as duckweed and water-fern may completely cover the top of the water. Also in certain environments it is not uncommon to find floating algae growing in such dense and large mats that the mosquito larvae have only a limited suitable environment.

The *Mansonia* mosquitoes should not be forgotten in a discussion on the relation of plants to mosquito production. The presence of suitable host plants for the larvae to use for attachment and for their oxygen supply are necessary for such mosquitoes.

A few years ago many articles appeared on plants that capture and kill mosquito larvae. Only one of these plants, the bladderwort, *Utricularia,* has received a great deal of attention. The bladderwort is an aquatic plant that has small bladders on the leaves in which mosquito larvae are entrapped and digested. No one has presented satisfactory evidence that these plants can control enough mosquitoes to be of any great value.

A great many people think that there are plants that are toxic or that produce substances that make the water toxic to mosquito larvae. There is a considerable amount of literature concerning the plant *Chara* which is said by some to produce a water environment unfavorable for mosquito larvae. Some claim that it produces so much oxygen that the larvae are killed. There is no uniform agreement among the specialists that this is actually so. In fact, one may find large mosquito populations growing in ponds containing a considerable amount of *Chara*.

There may be at least one exception. As you have heard for the past several years, some of the workers in California have been investigating the use of blue-green algae for the control of mosquitoes in rice fields. Their studies are as yet incomplete, but they seem to have considerable evidence that blue-green algae in some way, and they think in a toxic way, render the water unsuitable for the mosquito larvae.

What seems to be a constantly reoccuring folktale is that some plants are repellent to adult mosquitoes. In every community there is at least one plant said, by some local inhabitant, to repel mosquitoes. For instance in Florida, a number of years ago an investigation indicated that there were no mosquitoes on one of the Keys. The reason given was that the dodder or lovevine which was very abundant there was repelling the mosquitoes. Unfortunately, it was later noted that the other Keys also had dodder *and* mosquitoes. It has been found in all similar cases that there were factors other than the plants themselves responsible for the absence of mosquitoes.

Predators. Many members of the animal groups are predaceous on mosquitoes' eggs, larvae, pupae and adults. Hinman (1934, 1934a) surveyed the literature very completely and published a list of the various predators of mosquitoes, and included a large bibliography. If one would look into the literature during the period 1900 to 1934 he would find not only numerous titles regarding the use of predators for mosquito control, but he would also find sizable bulletins and published papers in the scientific journals telling of the merits of predators for mosquito control, and particularly on the use of fish. Of the predators, only fish are being used by man for mosquito control, but their use has been greatly reduced since the introduction of DDT.

Parasites. Parasites have been investigated to a less degree than have the predators. In 1927 Speer published an extensive list of the parasites of mosquitoes. There have been no promising additions since that time with the exception possibly in the protozoa.

The various parasitic organisms that we might be concerned with in mosquito control would be fungi, bacteria, viruses, protozoans and helminths.

Of the microorganisms, fungi, bacteria and protozoa reported from mosquitoes, probably only the protozoa belonging to the microsporidia are actually killing any appreciable amount of mosquitoes. There are a few records of parasitic helminths or worms, but the only ones of any interest at all are nematodes.

THE FUTURE OF BIOLOGICAL CONTROL. The title of this discussion is also concerned with the future possibilities of biological control of mosquitoes. Some comments and predictions will be made concerning the various biological control categories previously mentioned.

Some of the newer aspects of biological control may indeed be found useful. Certainly there is no known single cure-all for mosquitoes. Thus the mosquito control supervisors must use all the methods that will fit their particular circumstances.

Environmental Control.—It is expected that even greater use will be made of water level fluctuations and wave actions for mosquito control.

Altering the salinity or pollution of water will certainly receive continued use in the situations where the methods are applicable. I would consider the possibilities quite limited. In the water areas that are large in size such as large marshes, one could hardly expect to control the pollution of the water sufficiently to give satisfactory mosquito control to a community. That is, of course, assuming that the species are susceptible to the water pollution method. The same is true of altering salinity.

The use of plants for shade along stream margins can have some bearing on the control of populations of mosquitoes. Although not a means of reducing the production of mosquitoes, it is going to prove worthwhile to plan the landscaping around homes to reduce the harborages of mosquitoes. Except, perhaps, where the breeding area is limited, mosquito control cannot be materially affected by plants. Another exception may also prove to be in the use of blue-green algae which may prove practical at least in rice fields.

Predators.—Of all the predators, perhaps only fish will continue to be most useful, largely because their populations can be maneuvered by man, they are quite tolerant of a variety of water conditions, and they can be moved to water areas where they are needed. Fish probably cannot be useful in controlling mosquito populations in natural producing areas such as salt marshes or wide marshy areas unless there is some vegetation control. Certainly fish are useful in controlling mosquitoes in small situations like cisterns, barrels, ornamental ponds, small lakes and small ponds. The increased use of fish should be considered for future control although they seldom are the complete answer to mosquito control.

We do of course wait with great interest, the result of the introduction of *Toxorhynchites* into Samoa to control the *Aedes* vectors of elephantiasis (Peterson, 1956).

Parasites.—Probably the most likely place for investigators to concentrate their attention would be on parasites. Everyone is well aware of the microorganisms, the bacteria, the fungi, and the protozoa that do destroy mosquito larvae. These organisms have been found in routine examinations for parasites, but only in rare instances have people investigated the possibility of using the organisms for control. Many similar organisms can now be cultured; and in the future we would expect many more to be cultured. Today, with the big advancements in tissue culture it seems that there is an added possibility that some of the parasitic microorganisms could be cultivated and distributed in mass. Almost everyone is aware of the recent advances in the use of the bacterium causing milky disease for the control of grubs of the Japanese beetles. Likewise, the very spectacular spraying of viruses to control plant feeding insects (Bird, 1954; Dowden and Girth, 1953; Steinhaus, 1949; and Thompson and Steinhaus, 1950).

New experiments with microorganisms are showing us some of the most promising biological control of all times. There

is no reason why some of the microorganisms may not have an application in mosquito control. At least for the time being, use must be made of all the known methods for control.

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THE RELATION OF INSECT TAXONOMY TO MOSQUITO CONTROL *

P. W. OMAN

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Before attempting to outline the relation of insect taxonomy to mosquito control, I should like to make a few generalizations about the scope and objectives of insect taxonomy. I do this because I have the impression that taxonomy is sometimes poorly understood and too narrowly interpreted.

Taxonomy was once defined, by a well-known ecologist, as "that branch of natural science in which the blunders and banalities of the irresponsible and incompetent are perpetuated and respected." It is also looked upon by some workers, presumably taxonomists, as the ultimate in scientific investigations. The truth lies somewhere between these two extremes, we hope. According to my understanding, insect taxonomy is not an end in itself, but a means by which other objectives in entomology may be attained. It is not the entomological equivalent of stamp collecting. It is a method of investigation, useful as an aid in interpreting or clarifying observations, guiding experimental work and control operations, and providing working hypotheses.

Whenever an insect-control problem is encountered, one of the first questions asked about the pest is "What is it?" Taxonomy is directly concerned with that question. Under ideal conditions the answer can be given promptly and without qualification. Too often this cannot be done. Frequently the answer has to be couched in weasel words, something like "This is close to so-and-so, but not the same, and it may be a distinct species." Under such circumstances the taxonomist must rely upon subjective reasoning, knowledge of the group in question and,

* Based on an invitational paper given at the joint meeting of the American Mosquito Control Association and Florida Anti-Mosquito Association, Miami Beach, Florida, April 28–May 2, 1957.

most of all, upon ideas of classification that he hopes are sound. If the classification—i.e., the organized framework upon which the various subspecies, species and genera are arranged—is sound, then the identification, even though not complete, has value, because it correctly reflects the relation of the unknown to known elements. Having established this association, certain deductions can be made. Biology, probable relation to disease, general geographic origin, and other matters pertinent to research or control problems can at least be "guesstimated."

Before proceeding further I should like to discuss what may be called the "economics of insect taxonomy." Most entomological taxonomy is based on a study of the comparative morphology of the insect group under consideration. This does not mean that taxonomists are unaware of the importance of such refinements as culturing, serology, paper chromatography, and so on as means of interpreting relationships or defining specific concepts. I can assure you that most taxonomists utilize these approaches whenever opportunities permit. However, I can also assure you that, until taxonomic entomology is much better supported financially, the basic approach to identifications will continue to be by study of comparative morphology. This is simply a matter of economics and expediency. The identification of an insect by means of comparative morphology takes from a few minutes to a day or so, provided adequate literature and reference collections are available, and costs relatively little. By contrast, the identification (bacteriologists and pathologists call it diagnosis) of disease organisms requires considerable time for culturing, and usually costs much more. Call it analysis, diagnosis, or identification, the results are the same. You pay for the answer to "What is it?" It is fortunate that insect identifications can be accomplished at bargain rates—the economy of entomological operations simply will not support markedly higher costs of service identifications.

Taxonomic entomology has come to be recognized as the official custodian of materials, knowledge, and experience accumulated during the course of our long association with insects. This accumulated knowledge is so extensive that entomologists, no matter how well trained, who are required to operate for extended periods of time "on their own" must call on some central repository of knowledge for assistance in connection with their problems. The relation of taxonomy to mosquito control operations is well illustrated by activities that were carried on during World War II and subsequently.

Early in World War II the Army, Navy, and Public Health Service began clamoring for dozens of nonexistent *medical* entomologists. When it finally became apparent that adequately trained medical entomologists could not be obtained, an intensive training program was initiated. During the period 1942 through midyear 1945, personnel of the U. S. Department of Agriculture instructed 265 officers of the Army, Navy, and Public Health Service in the identification of medically important anthropods. Other agencies and the Armed Services conducted similar training programs. The periods of training varied from a few days to several weeks or months. Even so, these personnel found that they must constantly call upon taxonomic specialists to identify uncommon forms encountered, and to supply data on their biologies, distribution, and relation to diseases. As a result, thousands upon thousands of insects were channeled to Washington for identification, many of them with urgent requests for immediate reports.

Not all requests came from troops in the field. Prior to June 1942, upon specific request from the Office of the Army Surgeon General, the taxonomic unit of the Department of Agriculture supplied concise, organized data on insects of medical importance occurring in various parts of the world, with special emphasis on malaria vectors. The territory covered included all countries bordering the Medi-

terranean, Rumania, Arabia, Iraq, Iran, India, Burma, South China, Malaya, the Philippine Islands, Australia, New Zealand, and the islands of the South and Southwest Pacific. Information dealing with insects of the Australian and Oriental regions was also made available, upon request, to the Bureau of Medicine and Surgery, Navy Department. In 1944 an annotated bibliography of the literature dealing with the yellow fever mosquito, covering more than 1,200 published papers, was prepared upon request for the U. S. Public Health Service. U. S. Department of Agriculture taxonomists worked in close cooperation with the Medical Intelligence Branch of the Surgeon General's Office, furnishing whatever information was available on the distribution and habits of various species and their importance as pests or as vectors of human diseases.

You are familiar with the work known as "Global Epidemiology." Investigators engaged in the compilation of parts of this work contacted various agencies for assistance and guidance, and it was inevitable that taxonomists would be called upon. One investigator, whose task was to assemble information on the mosquitoes of South America, spent nearly two years at the U. S. National Museum with Alan Stone and the accumulated files in his custody.

You are also familiar with the theory and practice of selective mosquito control, sometimes referred to as species sanitation. Such practice permits maximum utilization of limited budgets and has an integral part in the establishment of priorities in work. The identification of the species to be controlled is, of course, a prerequisite for a species sanitation approach. As an example of important operations that have depended upon a thorough understanding of the species involved, I mention the solution of malaria transmission in southern Europe through an understanding of the *Anopheles maculipennis* complex, which provided a logical explanation as to why malaria was practically nonexistent in some localities, even though the *Anopheles* population was high, and prevalent in other regions with considerably lower *Anopheles* populations. Another example is the solution of the *Anopheles gambiae* problem in South America, where a knowledge of the species and its habits permitted eradication to proceed on a species basis. There is also the solution of a malaria-transmission problem in Trinidad after identification of the vector as *Anopheles bellator,* a species that breeds in bromeliads high in the trees. There undoubtedly have been many similar operations involving control of pest species.

Any detailed review of the development of knowledge of mosquitoes will reveal the essential part that taxonomists have played in the accumulation and organization of that knowledge. Information so assembled forms the basis for the preparation of mosquito handbooks and guides to their control. In the 1930's the U. S. Department of Agriculture undertook a survey of the mosquito fauna of tidewater Maryland, using light traps as a sampling method. This survey required the identification of over 60 thousand mosquitoes. Without the identifications, the survey would have been meaningless, so far as ideas of species abundance was concerned. The effort devoted to identification probably totaled more man-hours than all other aspects of the work combined.

As an outgrowth of the need felt by military personnel during World War II, there was envisioned in 1950 the preparation of pictorial keys to mosquitoes of medical importance for various regions all over the world. After some preliminary discussion, the job of preparing such keys was delegated to the taxonomic unit of the U. S. Department of Agriculture. Sixty-seven keys were prepared by 1954, and some of them have been published in *Mosquito News.* After completion of this series of keys, their probable use and adequacy was carefully considered, and it was decided to expand their usefulness by adding information on relation of spe-

cies to diseases, their biology, ecology, and other pertinent information, as well as accounts dealing with other common, though not medically important, mosquitoes occurring in the different regions. That job has now been completed, and a comprehensive work on the mosquitoes of medical importance for the world, including all the pictorial keys, is being published by the Department of Agriculture.

In 1954 Alan Stone and Kenneth L. Knight joined efforts in the preparation of a synoptic catalog of the mosquitoes of the world. Aided by a grant from the Office of Naval Research which permitted hiring of a capable assistant in October, 1955, this work has progressed rapidly, and we hope the project can be completed by mid-year, 1958. This basic reference work will certainly be indispensable to mosquito-control workers all over the world.

It might logically be asked, "If this job takes only three years, why wasn't it done long ago?" The facts of the matter are that the catalog will not have been prepared in three years. Alan Stone spent a great deal of time during the 25 years prior to 1955 preparing a card index to the mosquito literature. Nearly all of this was done on personal time—i.e., outside of official hours—and both Stone and Knight have continued this project largely as an extra-curricular activity. Add to this the information accumulated by earlier workers, and the official time of technical literature abstractors employed by the U. S. Department of Agriculture who have materially aided in this work, and you begin to appreciate the immensity of the task of organizing part of our existing knowledge of a relatively small group of insects.

I alluded previously to the possibility of making deductions about mosquito biology on the basis of a knowledge of the taxonomy of the group. Deductions such as I had in mind might be made like this. For a number of years investigators in the Far East, notably Japan, have been trying to find how *Culex tritaeniorhynchus* passes the winter months. Because this species is believed to be the principal if not the only vector of Japanese B encephalitis in Japan, details of its life cycle could be important in the control of the pest and thus in lowering the disease rate. Taxonomically, *tritaeniorhynchus* is assigned to the typical subgenus *Culex*, all known members of which overwinter in the adult stage in temperate regions. It follows that *tritaeniorhynchus* should conform to this overwintering pattern, although to date the most intensive searches have failed to reveal any overwintering stages of the species in Japan. By a similar line of reasoning other South East Asia species of the subgenus *Culex* are considered prime suspects as vectors of Japanese B encephalitis or closely related neurotrophic viruses.

Attempts to predict the pattern of future relations between insect taxonomy and mosquito control are naturally largely speculative, and highly colored by past experiences. Almost certainly future taxonomic research on problems related to mosquitoes and mosquito control will continue along the same general lines as it has in the past. We hope that these investigations will permit us to answer questions as they arise, but it is apparent that we cannot always anticipate what the needs may be.

The normal movements of human populations in their search for living space periodically bring large segments of humanity in contact with regions favored by mosquitoes. Extension of irrigation practices in the Western United States in recent years has resulted in mosquito problems where none existed before. We have also experienced increased demands and pressure from wildlife interests for preservation of large areas for recreation and wildlife reserves. It is reasonable to believe that these trends will continue, and bring demands for more and better mosquito control. New methods of attacking the problem will surely be sought and, in the seeking, taxonomic entomology will be called upon to render assistance.

For example, consider the chain of events that might occur if biological control of mosquitoes is thoroughly investigated. The natural enemies already present must be studied and their importance assessed. Other regions of the world must be scrutinized for worthwhile predators that might be introduced. The ecology, habits, and biotic potential of both predators and prey must be carefully studied. All these processes will require identification of insect material, and one step in particular—i.e., the world-wide search for useful enemies of mosquitoes—is likely to be guided from the very beginning by information assembled by taxonomists.

Or assume that, as a means of control, a change in the ecology of mosquito-breeding areas is contemplated. Again extensive surveys and studies requiring taxonomic assistance will be necessary.

Two comparatively recent developments may have a profound effect on future mosquito control methods. These are the resistance of insects to insecticides, and the insecticide-residue problem. If chemicals become ineffective, or hazardous to humans, domestic animals, or wildlife, the tendency to seek other methods of control will be accelerated. We hope that taxonomic entomology can keep pace with the demands for information that will be imposed upon it by these new approaches, whatever they may be. If budgets become even less adequate in proportion to the mosquito-control problems at hand, even further refinements of the species sanitation approach appear inevitable. Ventures into little-known regions of the world will necessitate working with relatively unknown faunas, for even a group of insects as well studied as the mosquitoes is still poorly known in some regions. In the solution of all these problems taxonomists will play an important part.

Finally I should like to refer to that most important contribution that taxonomy makes to applied entomology—namely, the supplying of a means of organizing and communicating knowledge about insects. A. B. Gahan (Proc. Ent. Soc. Wash. 25(3):73) stated the situation concisely in 1923. I quote. "Objects without names cannot well be talked of or written about; without descriptions they cannot be identified, and such knowledge as may have accumulated regarding them is sealed; unclassified, their relationships are unknown and the possibilities of deduction are destroyed. In short, without the fundamental work of the taxonomist the great mine of entomological literature would not exist, and the accumulation of knowledge would be largely limited to what one could personally observe and remember."

REPORT OF MOSQUITO CONTROL IN VIRGINIA

R. E. DORER

Prior to 1933 the only mosquito control work in Virginia was that conducted in limited areas for the control of malaria. With the introduction of the various relief agencies through the 30's many communities in the Tidewater section of the State carried on locally sponsored, federally financed projects. During World War II the Malaria in War Areas program carried on numerous projects around war establishments. When federal funds came to a halt, a real effort was made in Virginia for local communities to take over.

A state law was passed in 1940 providing for the establishment of mosquito control districts. As the federal assistance was reduced, local mosquito control districts were created to continue and expand the

control work. Mosquito control in Virginia is based on the concept that the local people receive the benefit and therefore, they should pay the cost. However, the Virginia law does allow for a state contribution of 25 percent of the funds collected locally, not to exceed $10,000.00 to any district in one year. This state aid is a great help to the smaller districts but is not the controlling factor in the creation of new districts.

The first mosquito control district was created in 1940 at Virginia Beach. No doubt there would have been more created at that time except for the war. At the end of the war a drive was made to establish more districts in areas where mosquito control was economically sound. To date there are 15 operating districts giving protection to about 1,000,000 permanent residents. There still remain many areas in Virginia where the mosquitoes are bad and where no mosquito control is carried on. However, these are sparsely settled areas where the cost of mosquito control cannot be economically justified. As land develops in the future, and the population increases, there naturally will be an expansion of the mosquito control activities.

In 1947 it was felt that an association was needed to unite the efforts being made in the state, and the Virginia Mosquito Control Association was born. The late Perry W. Ruth was the first president. Since that time the Association has grown and to a great extent has fulfilled its purpose for being. The official organ of the Association, "The Skeeter," is mailed regularly to over 400 persons.

Ten annual meetings have been held. The Association has assisted in securing additional state funds. Through the Association, cooperative projects with the various mosquito districts have resulted in the saving of thousands of tax payers' dollars. The Virginia Mosquito Control Association is a healthy organization because it is a "do" Association. In looking back over the years it would be hard to pick out the most significant event. But, perhaps the most far reaching decision was the one made by the Virginia State Health Commissioner in 1936; when he ruled that all *pestiferous* mosquitoes were a health problem regardless of whether they were proved carriers of disease. Today this concept is generally accepted.

In Virginia we think that it is better to eliminate mosquito breeding waters than to treat with an insecticide. Nevertheless, resistance is our most serious problem. We have used DDT with effective results since the war; but in some areas we now strongly suspect that we have resistant mosquitoes.

In the more heavily populated areas, where mosquito control is so necessary, there are strong factors at work which, if properly promoted, can result in greatly reducing mosquito-producing areas. Perhaps the worst breeding areas in eastern Virginia are the salt marshes. With the increasing population and a demand for more home sites, with the increased value of waterfront sites and with the recent growth of small boat activities, these marshes now appear as potentially valuable. One cannot justify reclaiming marsh land in the name of mosquito control but if the land is reclaimed for other purposes the mosquito problem is permanently solved. In Virginia, limited success has been obtained by this indirect approach.

The Virginia program is a control program. The people pay their taxes to reduce the mosquito annoyance and none of the funds are earmarked for research. Therefore, Virginia has contributed little to the knowledge of mosquito control. We are dependent on the information we get from other areas at these mosquito meetings and through *Mosquito News*. We are grateful to all who have shared their knowledge with us.

MOSQUITO CONTROL WORK IN MARYLAND

GEORGE S. LANGFORD
State Entomologist, University of Maryland, College Park

Mosquitoes and their control are of great concern to many people in Maryland, especially those living in tidewater communities. Outdoor living in many communities becomes difficult and at times impossible during mosquito season. The farmer, his help and his livestock, are adversely affected. Stockmen and dairymen suffer great financial losses. Agricultural workers lose efficiency and at times refuse to work because of mosquitoes. Development in recreational and resort areas is frequently hindered and real estate values are often depressed as a result of mosquitoes.

Organized mosquito control based upon state appropriations earmarked for mosquito control is new in Maryland. The first such appropriation was made available and effective beginning July 1, 1956. However, work for the control of mosquitoes is, of course, not new in Maryland. Since the turn of the century limited work has been done in various communities throughout the state for mosquito control. During the early thirties, which were depression years, extensive work for the control of mosquitoes was done through the Civil Works Administration and the Civilian Conservation Corps. With the Civilian Conservation Corps over 15,000 acres of marsh were ditched by constructing over 3,000,000 linear feet of ditches. Since World War II many cities, towns, and communities throughout Maryland have operated mist blowers and fog machines for temporary relief from mosquitoes.

In 1939 the first law applying directly to mosquito control was passed. That year the General Assembly of Maryland empowered the State Board of Agriculture to do mosquito control work. Under these enactments the State Board of Agriculture through the State Entomologist or its duly authorized officer or agent is authorized and empowered to make inspections, investigations, and studies to the extent to which funds are available for mosquito control work. The Act authorized the construction and maintenance of ditches, dikes, dams, and other facilities as well as authority to place or spread such insecticides as may from time to time be desirable or necessary to control or eliminate mosquitoes.

The State Board of Agriculture through the State Entomologist or duly authorized officer is also authorized and empowered to receive from any county, municipality, or special taxing district, in the state, funds for use in mosquito control work. The Act further authorizes contracts with any county, municipality, or special taxing district with respect to work or construction in connection with mosquito control. In addition, the State Board of Agriculture through the State Entomologist or its duly authorized officer or agent is authorized and empowered to acquire in the name of the state such property, easements, and other rights as it may from time to time deem desirable and necessary to carrying out the provisions of the law pertaining to mosquito control. Authority for purchase or condemnation is also provided in the law. The State Board of Agriculture is also authorized to accept aid, gift, or loan as may from time to time be made available by the government of the United States or any agency thereof for the purpose of carrying out the provision of the Maryland law.

As already noted, the first statewide appropriation for anti-mosquito work was made by the 1956 Legislature. The budget carrying the appropriation reads, in part, as follows:

". . . at least $213,690 shall be made available specifically for mosquito control and for no other purpose, and shall be expended for such control work through-

out the State only under the following conditions:

(a) Temporary work for the alleviation of acute annoyance by mosquitoes, . . . shall be undertaken only upon the condition that the municipality or special taxing area involved shall agree in writing to defray at least 50 per cent of the total cost of such temporary work, and

(b) Permanent work, such as upland ditching, marsh ditching, filling, and the like, shall be undertaken only upon the condition that the municipality or special taxing area involved shall agree in writing to defray at least 25 percent of the total cost of such permanent work.

(c) The determination whether any such work is of temporary or permanent character so as to fix the amount of the contribution by the municipality or special taxing area involved shall be made by the State Entomologist and the Dean of Agriculture, or by some other official designated by the State Board of Agriculture."

CONTROL WORK IN 1956. Mosquito control work under the appropriation just mentioned was started promptly on July 1. Eighty-two cities, towns, populated communities, and recreational areas in eleven counties requested participation and cooperated in the mosquito control program. All of these communities were sprayed and fogged periodically throughout the summer for relief from mosquitoes. During the first three months of operation a total of 5,815 miles of street was treated with 84,900 gallons of spray mixture. This would represent the spraying of approximately 125,000 acres. In addition to the above, considerable spraying and fogging were done with local equipment but no records were kept of actual street mileage sprayed.

It was estimated that a population of over 100,000 permanent residents and over 1,000,000 summer transients in resort areas benefited from these treatments. The results from these insecticide applications were very favorable according to reports received from residents as well as studies based on catches made in mosquito traps before and after spraying.

In addition to the spraying and fogging work just mentioned, a number of projects involving upland ditching and marsh ditching are now under way. However, such operations require extensive preparation. Surveys must be made taking into consideration the best type of operation, the cost of the project, its maintenance, effects on wildlife, number of people benefiting, the extent of mosquito breeding in the area, and many other factors. Some of these preparations have been made, others started, and many remain to be made.

MOSQUITO CONTROL HIGHLIGHTS FROM NEW JERSEY

L. W. CAMPBELL

In bringing the greetings of the New Jersey Mosquito Extermination Association to this Annual Meeting, I would like to note that since the last AMCA meeting in Texas, the New Jersey Association has held two meetings, the 43rd and 44th annual affairs which are well known to many of you. The Proceedings of the 43rd Annual Meeting have been published and constitute a volume of some 210 pages. The 44th Meeting just concluded was attended by representatives from most of the eastern and central states. In connection with these meetings, our group regrets that it has not been possible to have a broader representation from the American Association's official families.

During the past year there have been several events in New Jersey mosquito control which may be of interest to you. Among the highlights was the enaction

of legislation attempting to modernize our mosquito laws and to tailor the control programs for more efficient solution of present-day problems. Under this legislation the State Commission was created, which among other responsibilities, has the obligation of reviewing the mosquito problem on a state-wide basis and allocating such state funds as may be available for bolstering county programs. This Commission is busily engaged in developing its program and preparing a state assistance budget. The Commission includes the Director of the New Jersey Agricultural Experiment Station as an ex-officio member and two members, Mr. William Dillistin, who is chairman and Mr. Jesse Leslie, who have had long experience with the New Jersey program. Mrs. Eleanore Martin, who was a member of the State Mosquito Control Study Commission which assembled the information leading to legislation, is also a member. Mr. George Spangenberger and Dr. Michael Pacicco are energetic citizen members new to mosquito work.

The state-supported program of aircraft spraying in our tide-water resort counties successfully completed its seventh successive year under the direction of the Experiment Station. At the present time the Experiment Station is also directing the allocation of a $75,000 state appropriation for aid to counties which is specifically earmarked for the construction and reconstruction of water-management installations. This rather limited fund is being applied to specific projects of high-priority in a few counties.

The New Jersey Association has taken a major part in the modernization of legislation and has carried forward its general program along the lines followed for many years past.

The 44th Annual Meeting Proceedings are being dedicated to the memory of Dr. Leland O. Howard, pioneer in all mosquito control, on the occasion of the 100th anniversary of his birth. The contributions of Dr. Howard were featured in the opening session of the program. Representatives from many states contributed to the formal session of the 44th annual meeting, which also included the survey of mosquito work throughout the world and contributions from Federal Agencies engaged in mosquito investigation, in an attempt to improve the appreciation of the administrative groups for technical and legal matters concerned with the increasingly complex problems of mosquito control in rapidly-developing New Jersey. A round-table discussion was held in one session which permitted the informal exchange of information on subjects of particular interest to this group. Local problems of high interest, such as research on viruses transmitted by mosquitoes, and up-to-date information on the use and effect of chemicals completed the program.

The New Jersey group, including many of those who would have liked to be present at this meeting of the American Mosquito Control group, continue their high interest in the national organization and, as President of the New Jersey Association for this year, I extend to you a warm invitation to visit our next meeting in New Jersey.

The deadline for submission of titles *and* abstracts for the annual meeting in February is November first. See notice on page 218.

MOSQUITO CONTROL NOTES FROM PENNSYLVANIA

RUSSELL W. GIES

The following is a very brief summary of the mosquito control work in the Commonwealth of Pennsylvania.

There is no State Mosquito Control Association as yet, but in addition to overall supervision and advice of the State Health Department of Pennsylvania, there are three active Mosquito Control Commissions—one, the Delaware County Mosquito Extermination Commission, Media (just outside the City of Philadelphia)—Russell W. Gies, Director and Executive Secretary; two, the Bucks County Mosquito Control Commission, Doylestown, Pennsylvania, and three, the Blair County Mosquito Control Commission, Hollidaysburg, Pennsylvania.

The work is being carried out under a recent revision of the law which places the responsibility for mosquito control work under the governing boards of each county, or in the case of cities or other local municipalities, with authorities which may be set up, or under local auspices, usually under City Health Departments.

The first Mosquito Control Commissions were established in 1935 but as the intensity of mosquito trouble in Pennsylvania is rather localized, there has not been the wide-scale control set-up for whole regions as has occurred in some other states; there simply has not been the demand for mosquito control work to that extent.

The most serious problems have been where fresh-water mosquitoes, primarily house mosquitoes and fresh-water swamp varieties have been troublesome. We have no salt marsh in the State but get occasional flights in from Delaware to the south, and possibly from New Jersey to the east, into some sections of southeastern Pennsylvania.

Also, the City of Philadelphia is doing considerable control work. Dr. Newell E. Good is Entomologist and Director, and is located in 624 City Hall Annex, Philadelphia.

MOSQUITO CONTROL IN NEW YORK STATE IN 1956

C. T. WILLIAMSON
Director, Suffolk County Mosquito Control Commission

It is very difficult to prepare a report concerning the mosquito control activities in the State of New York without being repetitious. At the 11th annual meeting of the American Mosquito Control Association, held in California in January of 1955, Dr. Donald L. Collins, State Entomologist of New York, reported fully and in detail on New York State activities. His report, of course, appears in those proceedings. Insofar as the information that I have been able to gather outside of Long Island, the contents remain virtually the same as reported by Dr. Collins. Therefore, to avoid a complete repetition of this part of his report, I shall confine my comments to the Long Island area.

We find on Long Island a peculiar set of circumstances. We have mosquito control work in part of the largest city in the world, New York City, two of the largest mosquito control organizations, and perhaps the smallest mosquito control organization in existence, with no state organization heading up their activities. Each must act as an independent unit and carry

on the work of solving their local problems, without the valuable assistance that a state organization supplies.

I would like to deal first with New York City. A great real of salt marsh lies within the city limits, not only in those counties that are part of Long Island, namely Brooklyn and Queens, but also Staten Island, Manhattan and the Bronx. Organized mosquito control in the City of New York has not been carried on for some years, but there has been work done under the jurisdiction of various city departments, namely the Health Department and Sanitation Department. As a result of lack of coördination it has been rather incomplete. Recent agitation has brought this problem to the attention of the city fathers, and it is my understanding that in 1957 work will be organized on a broad scale under the jurisdiction of the Health Department to bring much needed relief to the residents of the affected areas.

As an indication, it is interesting to note a comment that appeared in one of the New York City papers last summer, in which they complained of the mosquito annoyance to the passengers of the subway trains that cross the Jamaica Bay marshes. This was a new stretch of track and the trains were running at a slow speed. Mosquitoes emerging from the surrounding marshes were hitching rides on the subway trains to such an extent that the passengers suffered serious discomfort. The article went on to state that the Transit Commission was being requested to speed up the trains to outrun the mosquitoes.

A report to date on the work in the City of New York has not been available to me. However, I do know that some casual spraying was done through the aid of the police department helicopter. In 1956 one or two mist blowers and fog machines were pressed into service in the more seriously affected sections of the City.

NASSAU COUNTY. Nassau County has had countywide mosquito control since 1916 and is currently operated as a countywide organization under the Department of Public Works, administered by Mr. LeRoy Kinsey, Deputy Commissioner for the division. My summary of Mr. Kinsey's report is as follows:

"Nassau County is bounded on the north by the Long Island Sound. Here the terrain is high and hilly, tapering off toward the south shore, where it becomes flat and is bounded by the Atlantic Ocean. Within the bays on the south shore are some 145 salt marsh islands, ranging in size from an acre to fifty or more acres. On these islands an extensive ditching program has proven most effective. Adjacent to the upland there are approximately 10,000 acres of salt marsh marginal land on which almost 800 miles of drainage ditches are maintained. There are also approximately 250 miles of upland streams and ditches to maintain for mosquito and flood control.

"Over 39,000 street catch basins are sprayed during the breeding season and some 2,500 other permanent breeding areas listed—such as ponds, swamps, pools, wet areas, etc., that are inspected and treated by chemical methods.

"In 1956 a total of more than 250 miles of ditches on the salt marsh and over 370 miles of fresh water streams were reconditioned. The maintenance of county open storm water drains required the clearance of 177 miles. The maintenance of the open storm water drains is under our jurisdiction and requires the services of approximately 40 percent of our personnel and equipment."

SUFFOLK COUNTY. Suffolk County is the only county in New York State that operates under a mosquito control commission on a countywide basis, and has been operating in this manner since 1934. The authority for this commission is established under a section of the New York State Public Health Law, which is in many respects similar to the laws establishing commissions in California, New Jersey and other states of the Union. This law has been amended from time to time to bring the operation of the commission up to date. The last amendment made to this law was enacted in 1956, and this removed the limit on appropriations that could be made to the mosquito commis-

sion. Appropriations formerly were limited to ⅝ mill per dollar of assessed valuation. The law, as it now reads, allows the local governing body, the County Board of Supervisors, the power to decide the amount of funds that will be provided to the commission.

Suffolk County is a large county. It is over a hundred miles from its west border to its eastern extremities. Much of the area is indented by bays and inlets, all of which have substantial salt marsh on their fringes. Seventy thousand acres of salt marsh border these bays and inlets. This marsh has been ditched and drained, and is maintained on a schedule of complete recleaning every two years. In the upland there are an estimated thirty thousand acres of fresh water swamps.

Long Island has experienced perhaps one of the most rapid population increases that has occurred in the country to date, and Suffolk County, of course, has had its fair share of this growth, doubling in size in the past six years. This has brought a tremendous increase in the work load of the Suffolk County Mosquito Control Commission, involving thousands of new catch basins in developments, the interruption of normal upland drainage, and the filling and interruption of drainage of the salt marsh areas.

The county was serviced by 25 pieces of mobile equipment; 3 boats and 6 fog machines were used on the adulticiding program. During the peak load periods in August, these machines were operated on a 16-hour per day schedule. Drainage on 35,000 acres of salt marsh was reconditioned and approximately 300 miles of upland streams and ditches were cleaned and re-channeled. Larviciding materials used were:

187,000 gallons #2 fuel oil
114,500 spray gallons—DDT emulsion
7 tons technical DDT.

A research program, jointly operated by the Suffolk County Mosquito Control Commission and the New York State Science Service, continued its studies of nuisance insects other than mosquitoes. Experimental applications of 2½ percent dieldrin impregnated granules were made for the control of greenhead flies. This work will be expanded into areas for residual control of *Aedes sollicitans* in 1957.

Orient Point Mosquito District is probably the smallest mosquito control district in the northeastern part of the country. This district is located at the easterly end of the north fork of the Island and incidentally is wholly within Suffolk County. It is a small strip eight miles long and averaging one mile wide. This district was organized under Chapter 246 of the laws of 1916, and at that time it was provided with an annual appropriation of $800. This law was amended by Chapter 13 of the laws of 1926, which increased the appropriation to $1,500. A second amendment enacted by Chapter 70 of the laws of 1944 increased the annual appropriation to $2,000. The district has been operating under this annual appropriation since that time. Among the unique features of this law is the one which prescribes the method of organization. The law stipulates that the taxpayers of the district shall meet each September and elect a committee to conduct the affairs of the district. This committee shall not have more than seven members, no mention is made of the minimum number of this committee, and for some time it has been operating with a single member. They have expressed the desire to remain as an independent unit, and appear to be relatively satisfied with the degree of control that is being exercised there. This is entirely a farming community and their principal problem is the *Aedes sollicitans* emerging from the salt marshes bordering on Gardiners Bay.

Insofar as the upstate New York areas are concerned, I am going to refrain from reporting here other than to refer you to Dr. Collins' report in the proceedings of the 11th annual meeting of the American Mosquito Control Association in 1955. That is a matter of record and is most complete.

MOSQUITO CONTROL IN RHODE ISLAND, 1956–57

JOSEPH F. PANNONE
State Mosquito Control Supervisor

Mosquito control in Rhode Island is handled under the Public Laws of 1954, as amended, Chapter #3366.

Under this act, a city or town may set aside certain sums of money for mosquito control. Request is then made to the state for participation in the State Matching Fund Program, whereby each city or town is reimbursed for money spent. This is done on a percentage, based on the amount of state funds voted by the legislature, but not to exceed $3,000 to any city or town in any one fiscal year.

There are seven cities and 32 towns in the state. Seven cities and 20 towns are in the program. The 12 remaining towns do no control work at all. You can appreciate our problem when the uncontrolled land area is 630.19 sq. mi. and the controlled area is only 480.81 sq. mi.

Culex pipiens and *Aedes sollicitans* are still number 1 and 2 on our list of pest mosquitoes.

Mosquito control has been practiced in Rhode Island since the early 20's when work was done in and around Providence under the direction of Prof. Frederic P. Gorham of Brown University. He also conducted surveys for the City of Newport at the request of the Chamber of Commerce.

Since the end of W.P.A. all control work is done under State Department of Agriculture and Conservation supervision. Ninety percent of our work is basic; ditching, draining and water control, with about 10 percent spraying wherever other methods cannot be used.

The greatest achievement in our control efforts was reached during the days of W.P.A. when the most notable project was the corrective work done on Prudence Island in the township of Portsmouth, R. I.

The greatest contribution in 1956 was the cleaning up of about 125 acres of filthy, mucky, state-owned marsh land, and turning it into a well-kept bird sanctuary that can be traversed by foot from one end to the other. This area is at Galilee, in the town of Narragansett, R. I.

The greatest contribution that is being made by the state is the matching fund program. The state also maintains a year-round crew, supplemented by a summer crew to do control work on state-owned lands. It also aids cities and towns with technical and supervisory help through its Division of Entomology and the State Mosquito Control Supervisor.

The Northeastern Mosquito Control Association has just had a successful annual meeting in our capital city—Providence—and from this meeting and the knowledge gained from the various speakers, the Rhode Island Budget Commission has seen fit to recommend a 60 percent increase in our matching fund program.

During the year 1956 we were stricken with the dreaded eastern equine encephalomyelitis. There were no recorded human cases, although 2 were suspected.

Here are some figures compiled for 1955 and 1956, on encephalitis in Rhode Island:

	1955	1956
Humans	0	0
Birds	—	801
Horses	15	8
Game farms	6	2
Horse and pony farms	15	8
Wild pheasants	3	0

I feel that all state agencies—district, sectional or regional-abatement groups, development associations, and others interested in mosquito control—should bring pressure to bear upon the Federal Government for research work to be done on eastern equine encephalomyelitis as to its cause, its effect on man, and what, if anything, can be done as a preventive measure.

SUMMARY REPORT ON MOSQUITO CONTROL IN CANADA

C. R. TWINN [1]

Organized attempts to combat mosquitoes in Canada appear to have begun in southern British Columbia, nearly 40 years ago. Today, local mosquito control campaigns are conducted by various communities in every province across the country. In general, these efforts are on a modest scale, the annual expenditures in any one area rarely exceeding a few thousand dollars. An exception is Winnipeg, where an Act passed by the Legislative Assembly of the Province of Manitoba in 1954 provides "for the establishment, powers, and duties of the Greater Winnipeg Mosquito Abatement District," and a per capita levy is made to cover the cost of control.

The Royal Canadian Air Force and the Canadian Army annually apply control measures, both aerial and ground, against mosquitoes and other biting flies near military establishments, especially in northern areas, such as at Whitehorse, Y. T., Fort Churchill, Man., and Goose Bay, Labrador, where the biting-fly problem is often acute during the short summer season. Industry, particularly the mining and pulp and paper industries, periodically take action against these insects when they affect production. Mosquito control is also practised in some of the national parks, such as those at Banff and Jasper, Alberta; at Prince Albert, Saskatchewan, and in Prince Edward Island.

An account of the mosquitoes and mosquito control problems in Canada was given some years ago in *Mosquito News* (Twinn, 1949), and the results of more recent studies of these insects were summarized in the same journal (Twinn, 1955). References to numerous publications on Canadian mosquitoes are given in these two papers.

The Entomology Division, through its laboratories across Canada, assists in furthering mosquito control by conducting investigations, making surveys, identifying specimens, and giving information and advice. An illustrated publication on mosquito control (Twinn and Peterson, 1955) is available free to the public on request.

[1] Head, Veterinary and Medical Entomology Unit, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

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Spend Washington's Birthday in Washington! Then attend the AMCA meetings, February 23–26, 1958.

***Note:* Please remember to indicate which tour you wish to take by completing the form sent to you on August 30.**

REPORT ON MOSQUITO CONTROL IN THE STATE OF OHIO

P. BRUCE BROCKWAY, JR.
Superintendent, Toledo Area Sanitary District

Ohio has but one mosquito control agency, which happens to be the Toledo Area Sanitary District. This District comprises an area of 153 square miles and has mosquito problems ranging from *Aedes vexans* to *Anopheles quadrimaculatus*. A total of 47 different species have been found within the boundaries of this District, but the major mosquito problems in this area are *Aedes vexans* and *Culex pipiens*.

The District's major mosquito breeding conditions are caused primarily by the relatively flat terrain and wind tides from Lake Erie.

In our quest for further information concerning the state of Ohio, the various counties within the state were contacted and it was found that only 20 out of a total of 63 counties reporting indicated any mosquito control activity at all, and in these cases the work was done on a small local scale. Fifty-five of these 63 counties wanted more information in the field of mosquito control and 8 indicated no interest as no particular mosquito problem existed within the counties involved. In answering our questions regarding equipment and materials, the answers indicated that more emphasis had been placed on fogging than on spraying, and even this operation was done generally by a pest control operator under contract with a municipality.

At the present time we are working with the Ohio Agricultural Extension Service and the Ohio State Department of Health to find a means of getting correct information to those 55 counties which indicated desire for education in this particular field. I am rather certain that the 1958 report from Ohio will show definite advancements in mosquito control in the state.

MOSQUITO CONTROL IN ILLINOIS

W. J. BUCHANAN
Manager, The South Cook County Mosquito Abatement District

Early references to organized mosquito control work in Illinois record a State Health Department malaria control demonstration at Carbondale, in southern Illinois, in 1922 and a similarly sponsored mosquito control program at Ravinia Park, about 20 miles north of Chicago, in 1925. Broadening of interest in these efforts was materially assisted during the mid 20's by LePrince and others who, sponsored by the Gorgas Memorial Institute, were responsible for the formation of the Anti-Mosquito Board of Metropolitan Chicago. Subsequent to this, on July 7, 1927, the Mosquito Abatement Act became law and immediately following enactment, three districts were formed in the north part of the state and one in the south.

In reviewing material concerning the above history I was especially pleased to learn, as I know you will be, that our good friend and fellow member, Mr. Otto McFeely, President of the Des Plaines Valley Mosquito Abatement District, qualifies for the distinct honor as the "Father

of mosquito control in Illinois." Mr. McFeely's work, which resulted in specific mosquito control by the Chicago Sanitary District, predates the earliest of the above activities by exactly one year.

As indicated in the foregoing, the 1927 Mosquito Abatement District Act is the enabling state legislation providing for the organization of "Any contiguous territory having a population of not less than three hundred inhabitants. . . ." During the two decades following enactment of the law only four new districts were added to the original four, but since 1947 nine more have been organized, so that today nearly a thousand square miles and over one and a half million inhabitants are included in the seventeen organized mosquito control districts of the State.

As in many other mosquito abatement districts throughout the United States, Illinois districts must direct their primary control efforts against the floodwater species. Our common problem is the well-known *Aedes vexans* that, because of its particular habits, in our terrain and climate, is able to locate literally thousands of oviposition sites in areas of only a few square miles. In the past we have been dependent solely on the larval sampling method to locate and evaluate these sources. Obviously, this could be done only when the larvae were present. The alternative was to collect soil samples, flood them and await development of the larval forms. This latter method was both cumbersome and tedious, requiring considerable space for rearing specimens and care throughout the developmental period. Perhaps the most significant recent achievement in Illinois has been the development, at the University of Illinois, of a practical and rapid hydraulic method for separating *Aedes,* and similar eggs and their shells, from the soil. During the past year one Illinois district, using this method, processed about 1,750 soil samples from 1,150 suspected sources. Incidentally, 705 of the suspected sources were found to be positive on the basis of shells (history of past production) and/or eggs (future production potential). This technique has the effect of lengthening the handle of our dippers, thereby enabling us to locate and evaluate many more floodwater sites in any given year than has been possible in the past.

In conclusion, I might mention that the Illinois Mosquito Control Association although formed about 1950, has just held its Third Annual Conference. As with most newly reactivated organizations, we are working diligently to increase participation and revenue. At our April meeting it was reported that, due in a large part to an intensive drive for sustaining memberships, the Association is now solvent. Moreover, the active membership roll now lists some 110 individuals, and 14 voting memberships are in good standing (in Illinois each state or local governmental agency directly engaged or participating in mosquito control is eligible for a voting membership). We are looking forward to a continuing growth in mosquito control in Illinois during the next decade. Through the medium of our Association and its membership, we see the opportunity to assist this growth, especially by the active support of long overdue Federal legislation, through support of much needed state legislation to facilitate the annexation of new areas to existing districts, and in the dissemination of information to those interested in organized mosquito control in Illinois.

REPORT OF THE UTAH MOSQUITO ABATEMENT ASSOCIATION 1957

T. A. SCHOENFELD
Salt Lake City, Utah

The Tenth Annual Meeting of the Utah Mosquito Abatement Association was held at the University of Utah in Salt Lake City on March 8 and 9, 1957. The sessions were well attended by representatives of the mosquito abatement districts and other agencies interested in mosquito abatement in the state. A large delegation from California was present and participated in the program and Mr. W. C. McDuffie from USDA, Agricultural Research Branch, attended the meetings and presented a paper.

The Utah Association is particularly fortunate in having the Logan Field Station of CDC, U. S. Public Health Service, located in the state, as we enjoy the close support and the participation of Dr. Archie D. Hess, Director, and other members of the staff in the programs and affairs of the association, particularly at these annual meetings. The proceedings and papers of the Tenth Annual Meeting will be published and distributed.

The Utah Mosquito Abatement Association was organized on March 20, 1948. At that time there were four organized mosquito abatement districts in Utah. Since the organization of the Utah Association in 1948, annual meetings have been held each year in rotation in the different districts. The number of organized districts has now grown to eight, with two more counties considering the organization of districts. In addition a number of smaller communities in the state, not included in an organized district, are conducting mosquito abatement programs.

The first mosquito control in the intermountain west was the Salt Lake City Mosquito Abatement District organized thirty-four years ago through an act of the Utah State Legislature of 1923. This district has since operated successfully, with close cooperation existing between the Department of Entomology of the University of Utah, the Salt Lake City Commission, the Salt Lake County Commission, and the people of Salt Lake City and surrounding county. We are fortunate to have Dr. Don M. Rees, head of the Department of Entomology of the University of Utah who has been associated with the Salt Lake City District for some twenty-five years. The manager of the Salt Lake District is Glen C. Collett who received his training in Entomology at the University.

The Utah State law under which mosquito control operates provides that any city, county, or portion thereof with a population of more than 100 may create an abatement district. This enabling legislation provides for the establishment and financing of districts at a local level without approval from a state authority. The drafting of this law was largely the work of Col. J. A. LePrince of the U. S. Public Health Service at the request of the Utah State Health Department. This law has been cited by Gray *et al.* as an example of good legislation.

One of the most significant events in the control of mosquitoes prior to 1956 was the cooperative water management program entered into by Salt Lake City, Salt Lake County, and the Salt Lake City Mosquito Abatement District. This program has been in operation for several years with each of the cooperating agencies highly satisfied with its results.

During 1956 the further development of a cooperative program of mosquito abatement extending to all agencies concerned with water management was stressed, and some progress has been made with this program in establishing more effective water management on a

mosquito-producing fresh water marsh selected as an experimental area.

The people of Utah are aware of the advantages of mosquito abatement programs, as the abatement programs have been generally very successful in the organized districts. The state association has done much to coordinate and promote mosquito abatement in the state and to publish and disseminate the results of this work to others interested in mosquito abatement activities. We have tried to establish a close affiliation between the Utah Mosquito Abatement Association and the American Mosquito Control Association which we feel should represent the parent organization of all state and local control agencies. One of the memorable highlights of the Utah Association was when it joined with the American Association in the annual meetings of these organizations in Salt Lake City in 1952. We hope in the not too distant future we will again have this pleasure.

PAST AND PRESENT MOSQUITO CONTROL IN CALIFORNIA

HOWARD R. GREENFIELD

President,[1] California Mosquito Control Association, Inc.

AND

G. EDWIN WASHBURN

Secretary-Treasurer,[2] California Mosquito Control Association, Inc.

The preamble, so to speak, of the California Mosquito Control Association, began in 1903 in the area surrounding San Rafael. In 1905, community action was instituted against the salt-marsh mosquito in Burlingame in San Mateo County. In 1910, Professor Herms squared off on the anopheline problem when he and Harold Gray successfully demonstrated mosquito control techniques on the anopheline species in a little town called Penryn in the Sierra Foot Hills.

In 1915 the State Legislature was persuaded to add to the State Public Health Code those sections now better known as the "Mosquito Abatement Districts Acts." These statutes definitely tied mosquito control to public health. It should be stated at this point that the authors of the Legislative Act had great vision and foresight as they went beyond the mosquito and included arthropod vectors of public health significance. This alliance with public health has continued throughout the years to the present time.

During the years from 1915 to 1946 Mosquito Abatement Districts fought hard to gain ground against the constantly increasing mosquito problem. Their weapons consisted largely of shovels, more commonly known as "idiot sticks," and oil larvicides. In fact, this period in the history of California mosquito control could be termed the era of "Fuel Oils."

In 1946, recognition of mosquito abatement districts came swiftly with the unveiling of the then "new" chlorinated hydrocarbon insecticides. The period between 1946 and 1949 could be termed the marriage of mosquito control to chlorinated hydrocarbons. This marriage was short-lived, however, when attention was focused on the problem of species of mosquitoes becoming resistant to DDT. The

[1] Manager, Northern Salinas Valley Mosquito Abatement District.

[2] Manager, Turlock Mosquito Abatement District.

districts suddenly became conscious of the need to return to the source reduction programs which had guided early mosquito control men.

The number of Mosquito Abatement Districts has increased from twenty-one in 1942 to the present fifty-three active Districts providing protection to 33,000 square miles of area and 7,000,000 or more people. The last figure I gave is of little value in view of the rapid population growth occurring in our State.

This has been a very brief history of mosquito control development from the beginning to the present. It is the present and the future unknowns in mosquito control problems with which we are concerned. Therefore, we would like to present certain happenings, or trends, which we feel have some significance in mosquito control in California and, possibly, in other areas as well.

Let us examine the record as it relates to larval and adult control. We need only to mention briefly the chlorinated hydrocarbon family of insecticides and the tolerance factor developed by the mosquitoes —we have all experienced to some degree this particular problem. Now the question of tolerance to the phosphate family is here before us. According to recent work done by C. M. Gjullin and L. W. Isaak,* it has been demonstrated that *Culex tarsalis,* in the Fresno area, are 21–23 times as resistant to malathion as formerly; however, they are still normally susceptible to parathion. If we must mention "firsts" in mosquito control, we probably have the dubious honor of being first in the development of a species of mosquito which is resistant to one of the phosphate insecticides. We must continue to examine, evaluate, and test new materials as soon as they are available or our temporary control programs will be hard pressed.

Another trend of importance is the continued and increasing awareness of fly control by mosquito abatement districts. This awareness, in part, has been brought about by public demand, and, in part, by efficient mosquito control techniques. Through the reduction of adult mosquito populations, populations of other aquatic flies have become more discernible and this has resulted in an increased demand for the services of mosquito abatement personnel. Actually, one mosquito abatement district already has entered the field of fly control; one district has requested that a fly survey be made by the Bureau of Vector Control, State Department of Public Health; and a few others have, indirectly, become interested through their efforts to effect mosquito control measures in sewage holding ponds.

Another trend that has become apparent is that of weed control. When mosquito control agencies in California began to return to the concept of source reduction as an integral part of their control operations, it was only a matter of time before the need for weed control became apparent, if the effectiveness of a source reduction program was to be maintained. In fact, the Insecticide Committee of the California Mosquito Control Association, which brought forth "A Guide and Recommendations for the Use of Insecticides in California," has been given the responsibility of developing a similar pamphlet on the "Use of Herbicides by Mosquito Abatement Districts." This pamphlet will be ready for the press sometime late in 1957 or early in 1958.

Finally, I must mention that, in spite of the heavy winter rainfall and flooded conditions that prevailed throughout much of the State in the early part of 1956, the much-feared upsurge in mosquito populations did not occur. This was undoubtedly due, in part, to the excellent mosquito control programs that were executed very early in the season. Thus, I am happy to report that the year 1956 was good to us and we look forward to 1957 with renewed vigor and hope.

* Gjullin, C. M. and Isaak, L. W. (1957). Present status of mosquito resistance to insecticides in the San Joaquin Valley in California. *Twenty-fifth Proceedings. California Mosquito Control Association.* (In press.)

IMPORTANCE OF ORGANIC PHOSPHORUS INSECTICIDES IN MOSQUITO CONTROL IN CALIFORNIA

A. F. GEIB

Manager, Kern Mosquito Abatement District, Bakersfield, California

The mosquito problem in the Central Valley of California, associated in large part with the use of water for agricultural purposes, is one that has not been easily resolved. In an area such as this, where agriculture is a major source of income, the use of land for the production of crops is of prime importance, taking precedence over most other activities. Problems created by such use or activity are secondary, even though they may be of considerable concern to a majority of the population. Because mosquito control must be secondary to the production of crops, and because, for economic reasons, it is not always possible to provide the facilities and cultural practices that will produce crops without producing mosquitoes, we find it necessary and essential to carry on our larviciding practices.

In regions of agricultural economy it appears that mosquito larviciding will be a requirement in attaining reasonable control of mosquitoes, particularly where lands are being brought into production, or where older producing lands need improvement as well as cultural practices. As such improvements are, to a great extent, dependent upon economic factors and education, they are being approached on a long range basis.

By 1952 such a high level of resistance to all the chlorinated hydrocarbons had been reached that they were no longer of practical value for mosquito control in extensive areas of the Central Valley. When confronted with the inability to control mosquitoes with insecticides of the chlorinated hydrocarbon family, we found ourselves in an untenable and rather critical position. Abatement districts were expending considerable sums of public monies, yet mosquitoes were abundant, and the public quite unhappy. Urgency was the order of the day, and, to fill the breach, so to speak, came the phosphate insecticides, first in the form of EPN, then Chlorthion, and later malathion and parathion. As these materials came into use, highly effective control resulted, and at a reasonable cost. It is difficult to predict what might have happened to mosquito control in the Central Valley had we not been able to substitute the phosphates for the chlorinated hydrocarbons. It seems that one thing is sure, we would not be experiencing good mosquito control without phosphate insecticides.

By 1954, malathion, and, to a lesser extent, parathion, were being used as the insecticides of choice by ten districts in the state. The use of both of these phosphates has increased until at the present time, approximately one half of the 55 districts in the state are using one or both of these materials to some degree. Because it is much less hazardous, malathion is the one preferred by most districts, yet considerably more acreage is treated with parathion, which is used as a principal insecticide by eight or more districts.

Malathion is used primarily as an emulsifiable concentrate applied as a spray by hand, power and airplane at an average rate of .4 to .5 pounds per acre. Some use is made of the granular form and of aerosols for adulticiding. At .5 pound per acre, the insecticide cost amounts to 92 cents per acre. Parathion is used exclusively as an emulsifiable concentrate applied as a spray by hand, power and airplane at an average of .1 pound per acre. At this rate, the cost for this material is 30 cents per acre.

No special precautions are taken for the handling of malathion. In the case of parathion, because of its extremely high mammalian toxicity, special procedures

have been adopted and are rigidly followed. I will not attempt to review in detail all the features of these commonly practiced handling procedures. This information has been published, along with a great deal of additional data concerning insecticides used for mosquito control. This was prepared by a committee of the California Mosquito Control Association and published in July of 1956 in a booklet entitled "A Guide and Recommendations for the Use of Insecticides in California Mosquito Control." Copies of this informative booklet are available from Ed Washburn, Turlock, California.

At this time, I think it will suffice to point out three general precautions to be followed when handling parathion: (1) Make sure every practical step is taken to prevent contamination of handlers with the concentrate solution; (2) no dilution stronger than one half of one percent should be used as a spray by hand or power applicator; (3) it seems wise to establish a base cholinesterase level on everyone handling parathion. Most districts in California are doing this by determining a blood level on all operators on a monthly basis, or at least three times a year—pre-season, mid-season and post-season. With the establishment of a base cholinesterase, it is always simple to check anyone who might be suspected of having had an exposure, or to determine the degree of toxic reaction in the case of a known accidental exposure.

As previously pointed out, we began using phosphates in 1952—initially, EPN and Chlorthion; then malathion and parathion—these latter two insecticides quite commonly during and since 1954. For the three years, 1954 through 1956, incomplete reporting shows that the districts have used 123,436 pounds of malathion, treating approximately 301,686 acres; and 98,636 pounds of parathion, treating some 992,893 acres. During this time, there have been three or four recognized accidental exposures resulting in reduced cholinesterase levels, but in only one case was any treatment required. This was an instance where an operator had repeatedly sprayed his lower trouser legs, over a period of a week or so, with a dilute parathion solution to repel mosquitoes. Standard atropine sulphate treatment was instituted with recovery that was rapid and complete. To our knowledge, no known toxicological reactions other than to the operators just mentioned have occurred.

Most districts in California using parathion have found it a wise procedure to contact one or more local physicians to familiarize them with the district's program, the symptoms and treatment for parathion poisoning. Since very often the average physician will have had no experience with the diagnosis and treatment for parathion poisoning, this is just sound insurance which, fortunately, has been needed very little to date.

From our experiences in using the phosphates, it appears that there is little hazard associated with residue on feed or forage crops. To my knowledge, our use of malathion at .5 pound per acre and parathion at .1 pound per acre during the past three years has not resulted in any damage or toxic reactions in man, domestic animals, wildlife or fish.

You may have received the impression from this presentation that parathion is a material too hazardous to be used for mosquito control purposes or hardly worth the trouble. If so, I would like to correct that impression. Those who have used parathion for mosquito control purposes in California are extremely well pleased with it. To them, it has proven to be as effective as DDT, possibly more so when first used, and it is very easily handled when proper procedures are made a part of the control agency's program. Most districts have experienced no exposure problems, and the few that have developed have not been serious. We cannot, of course, overlook the economies of using parathion—a cost of 30 cents per acre for the insecticide.

LABORATORY STUDY OF THE RELEASE OF SOME ORGANIC PHOSPHORUS INSECTICIDES INTO WATER FROM GRANULAR FORMULATIONS

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The effectiveness of granulated insecticides against mosquito and sand fly larvae, particularly when a heavy cover of vegetation must be penetrated, has been pointed out by Whitehead (1951), Keller *et al.* (1954a, b), and Labrecque and Goulding (1954). Labrecque *et al.* (1956) reported studies comparing size and composition of granular formulations for control of mosquito larvae by the use of bio-assay tests both in the laboratory and field. Collins (1955) has pointed out the need for more information on the physical characteristics of formulations for a better understanding of their use in insect control. Since there is very little information on the properties of granulated insecticides, chemical assays were conducted at the Orlando, Fla., laboratory to study the behavior and release of some organic phosphorus insecticides into water when applied as granular formulations.

MATERIALS AND GENERAL METHODS. Five types of granular carriers—attapulgite (Attaclay), montmorillonite (KWK Volclay, bentonite), vermiculite, diatomite (Celite), and pyrophyllite (Pyrax)—were used in the tests. Attapulgite, vermiculite, diatomite, and pyrophyllite were screened to 16/20 mesh and montmorillonite to 20/30 mesh. Most tests were run with parathion, but limited studies were conducted with Chlorthion and EPN. Granular formulations were prepared by saturating the carriers with acetone solutions of the insecticides and evaporating the acetone with an air stream. Since acetone swelled and dispersed montmorillonite granules, benzene was used in its place. In some tests kerosene or Velsicol AR–60 was used as a solvent and/or Triton X-100 as a wetting agent. The insecticides were extracted from water with benzene and analyzed by the method of Averell and Norris (1948).

Tests using 250 to 400 ml. of water were made in glass jars 3⅛ inches in inside diameter, and those using 1 liter of water were made in beakers 4 inches in diameter. Samples of water for testing were withdrawn by aspiration to minimize disturbance. The temperature ranged from 80° to 90° F. From 2 to 6 replicates of each test were made.

TESTS WITH PARATHION. The first experiment was conducted to determine whether the parathion released into water was distributed equally. Two grams of attapulgite containing 1 percent of parathion were added to 1 liter of distilled water to give 20 p.p.m., and allowed to stand 24 hours. Then 25-ml. volumes were sampled at different levels in the container. After the sampling all but the bottom ¼ inch of water was aspirated and discarded, the granules were filtered from the remaining water, and a 25-ml. sample of the filtrate was analyzed. No appreciable difference in the concentrations of parathion was found in the samples from the top, middle, and ¼ inch from the bottom, being respectively, 3.9, 4.1, and 3.6 p.p.m. The filtrate from around the granules gave a concentration of 8.3 p.p.m., approximately twice that in the three other locations.

The next experiment was to determine the quantity of parathion released into 250 ml. of distilled water by 1.0-, 0.5-, and 0.25-gram samples of attapulgite containing 1 percent of parthion. After standing 24 hours, water samples from the middle of the water column were analyzed. Then 240 ml. of the water were aspirated and discarded and a new 240-ml. volume added. After another 24 hours other

TABLE 1.—Release of parathion into distilled water from different amounts of 1 percent attapulgite granules

Weight of Granules (grams)	First Volume of Water		Second Volume of Water		Total Percent
	p.p.m.	Percent	p.p.m.	Percent	
1.00	10.2	25	8.6	21	46
.50	6.9	35	6.4	30	65
.25	5.8	58	2.5	23	81

samples were analyzed. The results given in Table 1 show that increasing the quantity of granules increased the concentration of toxicant present in the water but reduced the percentage of the total released.

The rates of release of parathion into distilled water from 1- and 10-percent granules on five carriers were compared. Either 500 mg. of 1-percent or 50 mg. of 10-percent granules were added to 250 ml. of distilled water in each of six glass jars, which were then covered with watch glasses. Each jar was allowed to stand for 1 to 9 days, and then 25 ml. from the middle of each water column were analyzed. From the jars that were tested on the fourth day 200 ml. of water were removed, a new 200 ml. was added, and the concentration of parathion was determined after 3 more days. Table 2 summarizes the results of these tests. The formulations with 1 percent of parathion on attapulgite, vermiculite, and diatomite showed a faster rate of release than those with 10 percent. With the passage of time differences between the two concentrations were reduced. Granules with 1 percent of parathion on vermiculite gave the highest initial release rate. There was very little difference between the two concentrations on montmorillonite, and they were lower than 1-percent formulations on attapulgite, vermiculite, and diatomite. The parathion already dispersed in the water had a tendency to reduce the release rate. When the water was changed after 4 days, the new water accepted more parathion over a 3-day period than that accepted between the fourth and seventh days when the water was not changed, but less than that accepted during the first 3 days, except with montmorillonite.

TABLE 2.—Release of parathion into distilled water from five granular carriers. Dosage, 20 p.p.m. of parathion

Carrier	Percent of Parathion	In First Volume of Water (p.p.m.)						In Second Volume of Water (p.p.m.)
		1 day	2 days	3 days	4 days	7 days	9 days	3 days
Attapulgite	1	7.0	9.2	10.5	11.4	11.8	14.2	7.5
	10	3.4	5.8	7.7	7.8	10.2	11.8	6.7
Montmorillonite	1	5.0	6.7	6.2	6.8	7.9	9.0	7.0
	10	6.3	6.4	6.2	6.8	9.1	10.5	10.5
Vermiculite	1	9.2	9.5	11.8	12.0	13.0	13.1	7.7
	10	4.3	6.2	6.9	7.8	9.4	11.6	5.5
Diatomite	1	7.5	9.7	12.0	11.8	12.7	13.5	8.3
	10	3.9	5.4	6.7	8.0	9.2	10.7	5.1
Pyrophyllite	1	5.9	7.3	7.9	8.1	9.9	11.6	6.7

TABLE 3.—Adsorption of parathion after 24 hours on five granular carriers from water solutions containing 15.5 p.p.m.

Carrier	Parathion Concentration after 24 hours (p.p.m.)	Percent Adsorbed
Attapulgite	14.5	6
Montmorillonite	11.3	27
Vermiculite	14.4	7
Diatomite	13.9	10
Pyrophyllite	15.0	3

In the preceding tests, between 30 and 50 percent of the parathion was not released in 9 days. To determine whether adsorption was affecting the amount released, 1 gram of each of the granular carriers was added to 50 ml. of water containing parathion at 15.5 p.p.m. and shaken. Montmorillonite granules dispersed to form practically a colloidal suspension, so that it had to be centrifuged before sampling. Analyses of aliquots of the solution before and 24 hours after addition of granules showed that montmorillonite was the only material that gave a large amount of adsorption (Table 3).

TESTS WITH PARATHION, CHLORTHION, AND EPN AT 1 P.P.M. Tests indicate that the release rate is decreased as the water-saturation point is approached. The water solubility of parathion (20 p.p.m.) is approximately 2,000 to 20,000 times the concentration required for measurable toxicity response of mosquito larvae. At the concentrations used in tests against these larvae it is impossible to extract sufficient chemical for analysis. To obtain 50 micrograms from a 0.005-p.p.m. concentration would require extracting 10 liters of water. Consequently, the remaining tests were conducted at 1 p.p.m.

The amount of parathion released into distilled and marsh salt water from five granular carriers was determined. Either 100 mg. of 1 percent or 10 mg. of 10 percent granules were added to 1 liter of water in beakers, which were covered with watch glasses and allowed to stand 24 hours. Then 250 ml. from the middle of the water column were analyzed. Table 4 shows that, as in previous tests, 1 percent formulations on attapulgite, vermiculite, and diatomite released a greater amount than did 10 percent formulations. The two concentrations of parathion on montmorillonite released approximately the same amount into distilled water and gave the largest release. The amount released into marsh salt water was slightly less than that into distilled water except for the 10 percent montmorillonite granules, which showed a large decrease. The difference between the two concentrations is much greater in these tests than in those with parathion at 20 p.p.m. when attapulgite, vermiculite, and diatomite granules were used.

A series of tests were run to study the effect of including solvents and wetting agents in the formulation, or the presence of soil, on the amount of parathion released. Either 100 mg. of 1 percent or 10 mg. of 10 percent granules were added to 1 liter of distilled water, and 250 ml. of water sampled from the middle of the water column after 24 hours. The results, given in Table 5, show that the addition of 2 percent of kerosene or Triton X-100, or 1 percent of each, had no effect on the amount released in 24 hours from attapulgite, but the presence of Velsicol AR-60 or soil with diatomite granules reduced the quantity of parathion found in the

TABLE 4.—Parts per million of parathion released into distilled and marsh salt water in 24 hours from five granular carriers containing 1 and 10 per cent of the insecticide. Dosage, 1 p.p.m. of parathion

	Distilled Water		Marsh Salt Water	
Carrier	1%	10%	1%	10%
Attapulgite	.71	.25	.64	.18
Montmorillonite	.88	.92	.75	.17
Vermiculite	.85	.30	.63	.12
Diatomite	.81	.21	.71	.18
Pyrophyllite	.41	*	.28	*

* Impossible to formulate 10 percent parathion on pyrophyllite granules.

TABLE 5.—Parts per million of parathion released in 24 hours from granules containing various solvents and wetting agents

Carrier	Solvent or Wetting Agent	1% Granules	10% Granules
Attapulgite	None	.71	.25
	Kerosene 2%	.72	.25
	Triton X-100 2%	.70	.25
	Triton X-100 + kerosene, 1% each	.70	.27
Diatomite	None	.81	...
	Over 1 inch of soil	.56	...
	AR–60, 25%	.22	...
	AR–60, 25% over 1 inch of soil	.22	...

water. A concentration of 0.81 p.p.m. was obtained from diatomite alone in 24 hours, whereas the concentrations obtained from diatomite plus 25 percent of Velsicol AR–60 were 0.37, 0.41, 0.56, and 0.49 p.p.m. after 2, 4, 7, and 8 days.

A series of tests were run to compare the amount of parathion, Chlorthion, and EPN released into water at 4, 8, 24, or 48 hours. Either 40 mg. of 1 percent or 4 mg. of 10 percent granules on five carriers were added to 400 ml. of distilled water and allowed to stand for 24 hours, and then a 250-ml. volume of water was aspirated for analytical determination. Table 6 shows that the 1 percent granules of both parathion and Chlorthion on attapulgite, vermiculite, and diatomite granules released toxicant more rapidly than 10 percent formulations. There was not a large difference in release of parathion or Chlorthion, but insufficient EPN was present for analysis, indicating a much lower release. Both formulations on montmorillonite released about the same amount of toxicant, which was about the same as or larger than on other carriers. Essentially total release of parathion was obtained in 48 hours from 1 percent attapulgite and 1 and 10 percent montmorillonite granules.

DISCUSSION. In these experiments granules containing 1 percent of parathion showed a faster rate of release than those containing 10 percent, at dosages of both 1 and 20 p.p.m., except when montmorillonite was used as the carrier. Since both 1 and 10 percent granules were applied at the same dosages of parathion, the greater surface exposed to water due to the larger quantity of carrier present was probably responsible. The montmorillonite granules used were a type of swelling bentonite, and this accounts for the high release of parathion from 10 percent granules at the lower dosage. Because the granules swell and disperse, they either present a larger surface area for release

TABLE 6.—Parts per million of parathion and Chlorthion released from five types of granular carriers containing 1 and 10 percent of the insecticides

	4 Hours		8 Hours				24 Hours				48 Hours	
	Parathion		Parathion		Chlorthion		Parathion		Chlorthion		Parathion	
Carrier	1%	10%	1%	10%	1%	10%	1%	10%	1%	10%	1%	10%
Attapulgite	...	*	.40	*	.38	*	.62	.11	.53	.28	.97	.47
Montmorillonite	.42	.14	.57	.59	.51	.65	1.15	.76	.58	.54	.97	1.01
Vermiculite	.12	*	.34	*	.30	*	.51	.10	.30	.21	.78	.22
Diatomite	.22	*	.40	*	.43	*	.65	.14	.53	.30	.77	.32
Pyrophyllite	*	*	.35	...	.19	...	.41	...	.45	...	.52	...

* Not enough chemical present in volume of water extracted for the limits of the analytical method.

or actually carry the parathion into the water when they disperse as colloidal particles. At the higher dosage 1 percent montmorillonite granules released less than did other 1 percent granules. Since it was shown that the release is decreased near the point of water saturation of parathion and since montmorillonite granules adsorbed this chemical from water solution in this range, the slower rate of release probably results from an adsorption mechanism. Montmorillonite granules did not swell and disperse in salt water as much as they did in distilled water. This accounts for the decrease in amount released from 10 percent montmorillonite granules into salt water. The release rate of parathion and Chlorthion was about the same, while that of EPN was much lower. Based on previous bioassay studies, parathion appeared about twice as soluble as Chlorthion, and more than 100 times as soluble as EPN; so water solubility is apparently a factor in release into water.

SUMMARY. In laboratory tests chemical analyses of water treated with granular formulations of parathion, Chlorthion, and EPN in five types of carriers were conducted to study the behavior and release of toxicants into water. Sampling different depths of water treated with attapulgite granules containing 1 percent of parathion showed a uniform distribution of the toxicant between the top and ¼ inch from the bottom after 24 hours. Increasing the quantity of granular formulation added to equal volumes of water increased the concentration of toxicant present, but decreased the percentage of the total released.

Granules containing 1 percent of parathion showed a faster rate of release than those containing 10 percent except when montmorillonite was used as the carrier. These differences were reduced with the passage of time. Both concentrations on montmorillonite released at approximately the same rate and were, for the most part, lower than other 1 percent formulations at a higher dosage (20 p.p.m.) and equal to or higher at a lower dosage (1 p.p.m.). Parathion was released slightly less rapidly into salt water than into distilled water from all formulations tested except the 10 percent concentration on montmorillonite, which showed a considerable decrease in the amount released in a given time. The addition of 2 percent of kerosene or Triton X-100 or 1 percent of each of these showed no effect on the amount released, but 25 percent of Velsicol AR–60 decreased the rate of release. The release rate of parathion and Chlorthion was about the same, while that of EPN was indicated to be much lower.

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STUDIES WITH ORGANOPHOSPHORUS COMPOUNDS IN THE CONTROL OF *PSOROPHORA* LARVAE IN MISSISSIPPI RICE FIELDS[1]

WILLIS MATHIS AND H. F. SCHOOF

Large scale tests in rice fields of the Mississippi Delta with dieldrin as a preflood larvicide during 1954 indicated that *Psorophora confinnis* (Lynch-Arribalzaga) could develop resistance to this material when it was used extensively over large areas (Mathis, *et al.*, 1955). Since other chlorinated hydrocarbon insecticides offered little promise against this species, further studies were confined to organophosphorus compounds, some of which had proved to be effective in the control of other resistant species (Keller, *et al.*, 1953; Gjullin, *et al.*, 1954).

METHODS. In 1955, laboratory tests were conducted in which acetone solutions of Chlorthion, malathion, Dipterex, and DDVP were added to water from wells or streams commonly used for irrigation purposes. Approximately 300 ml. of water were placed in pint jars and the toxicant added to give the desired dosage. Ten larvae were then placed in each jar and left for a 24-hour period, at the end of which time the mortality was determined. All larvae which failed to respond when probed were considered dead. Each dosage of each material was replicated at least three times and three checks were used for each series. In tests to evaluate the residual action of the treatment, larvae were placed in the jars at periodic intervals and 24-hour mortalities obtained. Between tests, covers were placed on the jars to prevent evaporation.

In the field tests (1955) Chlorthion and malathion were injected as emulsions into the discharge hose of a pump (200 g.p.m.) by means of a solution feeder. In the plots where the number of larvae was insufficient to determine the effectiveness of the material used, water samples were collected in pint jars and *Psorophora* larvae introduced therein to obtain 24-hour mortality levels.

Granular formulations also were tested on a field basis in 1955. Bentonite pellets impregnated with Chlorthion (10 percent), malathion (1 and 5 percent), Dipterex (5 percent), and DDVP (5 percent) were evaluated as preflood applications. In addition, malathion (5 percent) on tobacco stems was tested. Plots of approximately 1,000 square feet each were treated in triplicate at the rates of 0.2, 0.4, and 0.5 pound per acre with each of the materials. Chlorthion and malathion also were applied at the rate of 0.75 pound per acre. Plots were flooded immediately after treatment and larval counts made 24 and 48 hours later by means of a square foot sampler (Horsfall, 1942). Chlorthion also was applied to two plots at the rate of 0.2 pound per acre as a postflood treatment.

In field tests during 1956, parathion and Dipterex were injected directly into the irrigation influent by means of a metering device attached to a 55-gallon drum (Gahan, *et al.*, 1955). Technical parathion, "solubilized" by adding four parts Triton X-100 to each part of parathion, was applied at the rate of 0.02 p.p.m. Dipterex was introduced at a rate of 0.25 p.p.m. as a soluble powder. Since Dipterex is soluble in water up to 13 to 15 percent, no emulsifier was necessary.

RESULTS. Results of laboratory tests with Chlorthion, malathion, Dipterex, and DDVP are shown in Table 1. Chlorthion was the most toxic material tested, giving 100 percent mortality at a dosage range of 0.0125 to 2.0 p.p.m. when larvae were introduced immediately after treatment and exposed for 24 hours. Malathion and

[1] From the Communicable Disease Center, Bureau of State Services, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

DDVP gave the same mortality at a dosage range of 0.1 to 2.0 p.p.m. while Dipterex gave essentially 100 percent mortality at a range of 0.25 to 2.0 p.p.m.

Chlorthion also remained toxic to the larvae for the longest period of time, killing all larvae at a dosage of 0.25 p.p.m. 14 days after being injected into the water. With DDVP and Dipterex, dosages of 1.0 and 2.0 p.p.m., respectively, were required to give 100 percent mortality at 14 days. At 2.0 p.p.m., malathion failed to kill all larvae 14 days after treatment.

The first field treatment was made with malathion at an estimated dosage of 0.5 p.p.m. Due to improper water management, only one terrace of approximately 0.25 acre was flooded directly by the pump. Sampling in this terrace failed to reveal any larvae 24 hours after flooding. Pint samples of water taken 12 hours after flooding from five different locations in the terrace gave 99 percent 24-hour mortalities of *P. confinnis* larvae introduced therein. No additional water entered the terrace for the following 24 hours. Water samples taken at this time were not toxic to *P. confinnis*.

A single terrace also was flooded with water treated with Chlorthion at the rate of 0.05 p.p.m. An insufficient number of larvae were present in the terrace to determine the effectiveness of the treatment. As the terrace was being flooded, sufficient water seeped through the lower dike to flood a part of the next terrace. Paired samples of water were then taken from the terrace flooded directly and from the terrace containing the seepage water. In five samples of water from the terrace flooded directly, the 24-hour mortality of *P. confinnis* larvae was 99 percent. In the same number of samples from the terrace with seepage water, no mortality occurred. After 24 hours, samples from both terraces gave mortalities essentially equivalent to those of untreated samples.

In a second test with Chlorthion, it was applied at a rate of 0.025 p.p.m. in an 8-acre rice field. Larval sampling 24 and 48 hours after flooding indicated that control was obtained only in the terrace into which the pump discharged. Below this point the larval densities were irregular but development continued. In a third plot of 3 acres, a dosage of 0.074 p.p.m. of Chlorthion gave control only in the first acre flooded.

The "solubilized" parathion was injected at a dosage of 0.02 p.p.m. into the flood water used to irrigate 94 acres of rice. For the first 4 days, all water from the pump (2,200 g.p.m.) entered a 31-acre portion (field 1) and fully flooded it. After this, only enough water entered this field to keep the soil covered.

In field 1, plot A (7.8 acres) was first sampled for larvae on a line following the field road (figure 1) about 12 hours after the intial introduction of the water. Small larvae were found in all terraces except those into which the water flowed

TABLE 1.—Percent mortality of third or fourth instar larvae of *Psorophora confinnis* exposed for 24 hours to different dosages of four organophosphorus compounds

	Percent Mortality								
	Parts per Million								
Chemical	2.0	1.0	0.5	0.25	0.1	0.05	0.025	0.0125	0.00625
Chlorthion [a]	100	100	100	100	100	100	100	100	90
Malathion [b]	100	100	100	100	100	97	57	[c]	[c]
DDVP [b]	100	100	100	100	100	73	0	[c]	[c]
Dipterex [b]	100	100	100	99	93	60	7	[c]	[c]

[a] Six tests at all levels except for three at 0.00625.
[b] Six tests at 2.0–0.25 p.p.m.; three at 0.1–0.025 p.p.m.
[c] No tests run.

directly from the canal. On the second day of flooding, second-instar larvae were found in terraces 1, 2, and 3 (figure 1). None were found beyond terrace 3 until terrace 11. Other terraces were only partly flooded by seepage water and no samples were made.

On the third day, plot A was fully flooded and water was running over the top of many terraces. Two square-foot samples per terrace on the third and fourth days revealed one third-instar larva in terrace 1 with other samples negative until terrace 8 was reached. Larvae were numerous in terraces 9 through 14. Samples also were made on the opposite side of field on same date, and from location of larvae in both lines of sampling the shaded area was made (figure 1).

No attempt was made to follow the

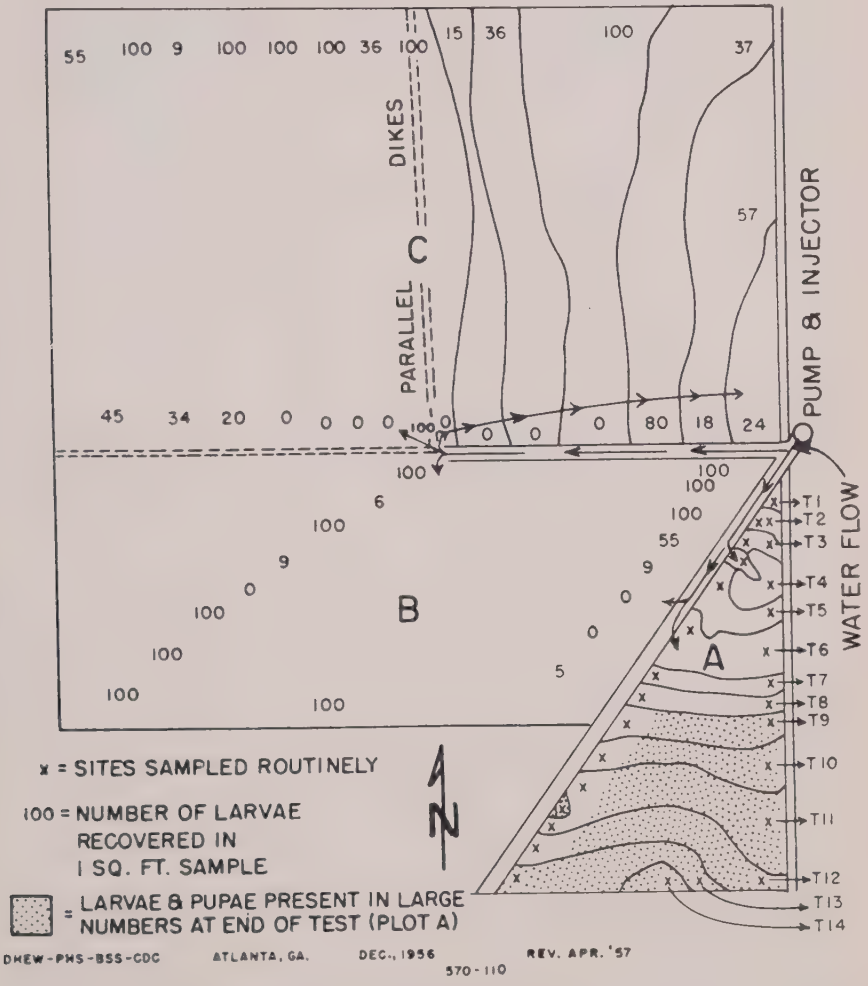

FIG. 1.—Plan of field 1 showing plot A (7.8 acres) and plots B and C (23.4 acres) and routine sampling sites and spot collection sites for mosquito larvae.

development of larvae in field 1 plots B and C (23.4 acres). However, 3 days after water entered plot B, samples were taken immediately after crossing each terrace along lines indicated in figure 1. Of 16 samples taken, only three were negative, several samples having over 100 larvae per square foot. The northern portion of the field, plot C, was sampled on the fourth day in a similar manner. Twenty-nine square-foot samples were made but only eight were negative. In this plot, 100 second-instar larvae were found in one sample at the end of the parallel dikes, about 20 feet from the discharge of the main canal. This area was flooded entirely by means of seepage water.

In field 2, plot A (figure 2) the water, after flowing through the canal, partially flooded the first 11 terraces within 24 hours. Subsequent flow of water was reduced and the remainder of the plot flooded more slowly. On the second day, square foot samples indicated small larvae in terraces 5, 7, and 8. Beyond this point, water was present only in the terrace ditches. On the third day, sampling of terraces 1 through 11 showed only the first three negative. On the fourth day these terraces were again sampled and larvae were present in the same locations. The numbers of larvae ranged from 9 to

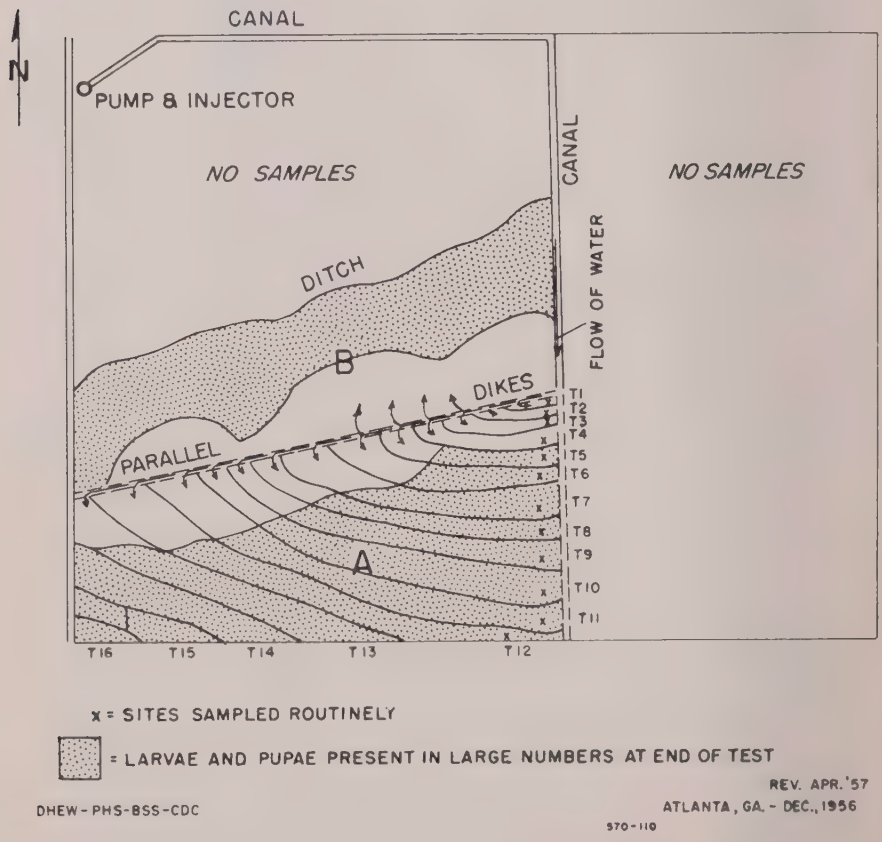

FIG. 2.—Plan of field 2 showing routine sampling sites for mosquito larvae.

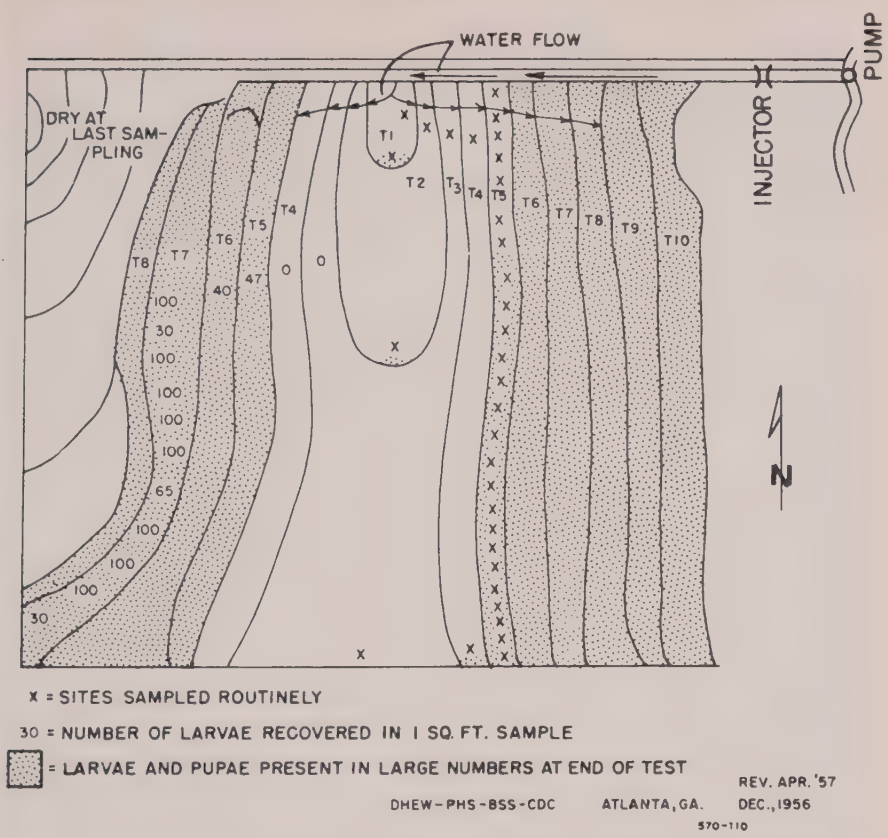

FIG. 3.—Plan of field 3 (28 acres) showing routine sampling sites for mosquito larvae.

over 100 per square foot in terraces 4 through 11. The shaded area indicates the area in which larvae were visible in terrace ditches on the seventh day. No square-foot samples were taken in field 2, plot B, but the location of the larvae on the seventh day was noted as in Plot A.

A 28-acre rice field was treated with Dipterex at 0.25 p.p.m. However, the delivered dosage was considered to be greater than 0.25 p.p.m. since the pump (1,600 g.p.m.) failed to deliver the rated discharge.

Flooding of the field began 5 hours before the Dipterex was introduced into the water. At this time, terrace 1 (figure 3) was fully flooded and water was flowing into terrace 2. On the second day, water was flowing through terraces 1, 2, and 3, with terraces 4 [2] and 5 being flooded by subsurface seepage. Larvae were found in each terrace, being numerous in terrace 5. On the third day as many as 33 larvae per sample were found at the end of terrace 1 farthest from the water entrance. No larvae were found in terraces 2, 3, and 4 but in terrace 5 breeding was heavy with many counts of over 100 larvae per square foot. On the fifth day, all ter-

[2] Subsequently surface water entered terrace 4.

races on the east side of the field were flooded. Terraces 1, 2, and 4 had larvae and pupae at the extreme south end. Terrace 3 was negative. In the northern third of terrace 5 the larvae had been killed from water overflowing into it from terrace 4. Beyond this point, counts as high as 100 larvae per square foot were found. On the sixth day, terrace 5 contained mostly pupae in locations sampled the previous day but the counts were lower.

Sampling of the west side of the field on the sixth day showed no larvae up to terrace 5. Beyond this terrace, larvae and pupae were numerous, densities as high as 100 specimens per square foot being found.

The preflood applications of granular preparations of Chlorthion, DDVP, malathion, or Dipterex to field plots failed to give any appreciable degree of control of breeding at the dosages applied. In the two plots treated with Chlorthion as a postflood treatment at the rate of 0.2 pound per acre, the 24-hour mortality of *P. confinnis* larvae was essentially 100 percent.

DISCUSSION. Although laboratory tests with Dipterex, Chlorthion, DDVP, and malathion indicated that *P. confinnis* larvae could be killed with low dosages (0.25 p.p.m. or less) subsequent field tests with Chlorthion (0.074 p.p.m.) and Dipterex (0.25 p.p.m.) in which normal flooding practices were followed failed to give satisfactory control over plots of 3 and 28 acres, respectively.

A similar field test with "solubilized" parathion at 0.02 p.p.m. also failed to give satisfactory control of breeding in a 94-acre field.

The most obvious reason for the failure of these compounds to control larvae under field conditions is the fact that when water containing these toxicants passes through soil as in subsurface seepage, the toxicant is either removed or rendered inactive. Definite proof of this detoxification was obtained in tests with the emulsifiable Chlorthion concentrate, "solubilized" parathion, and soluble Dipterex powder. The soil on which rice is usually grown in the Mississippi Delta has a tendency to crack when dry. Since many growers follow a practice of draining their rice fields about 1 month after the initial flooding and allowing them to dry thoroughly, a great deal of seepage occurs when these fields are reflooded. Since treated water which has passed through the soil of a contour terrace has been shown to be nontoxic to larvae, a dilution factor frequently begins after the first terrace is flooded and is increased as each lower terrace is flooded. If the dry fields had been saturated with water by rainfall just prior to the flooding, subsurface seepage would decrease and, presumably, the effectiveness of the treatment would increase.

Other factors such as the distance the water travels through the field and the time required (2 to 14 days) also may influence larval mortality but it was not always possible to separate these elements from the seepage and dilution factors in the tests conducted.

The above data contrast with those of Gahan and Noe (1955) who reported solubilized parathion at 0.02 p.p.m. to give complete control of *Psorophora* larvae in a 17-acre field in Arkansas. In their studies, the test plots selected had the irrigation canals along one edge at right angles to most of the transverse levees whereas in the Mississippi tests, the irrigation water usually entered the highest terrace and then progressively moved through the field to the lowest terraces. The latter type of irrigation is the usual practice followed by rice farmers. However, the significance of the seepage factor is emphasized by absence of control even in terraces flooded directly from the canals (figure 2). From these data, it is apparent that while parathion treated water can move through irrigation canals for distances up to 4,800 feet without marked loss of toxicity, the passage of the water through the rice field is the factor which determines the effectiveness of the application.

With the impregnated bentonite pellets

which were applied as a preflood treatment, it is assumed that the first water which entered the field carried the insecticide into the soil. Thus the toxicant was removed before sufficient water was available to flood the plot and hatch the mosquito eggs.

Summary. Laboratory tests with Chlorthion, malathion, DDVP, and Dipterex at the rates of 0.0125, 0.1, 0.1, and 0.25 p.p.m., respectively, gave 100 percent mortality of *Psorophora confinnis* larvae when they were introduced into treated water and exposed for 24 hours. Chlorthion introduced into irrigation water of 8 and 3 acre fields at the rates of 0.025 and 0.074 p.p.m. failed to give satisfactory control of *P. confinnis* larvae.

Field tests with "solubilized" parathion applied at the rate of 0.02 p.p.m. and Dipterex (soluble powder) applied at the rate of 0.25 p.p.m. gave satisfactory control of larvae only near the entrance of the water into the fields. The regular irrigation practices were not altered in any way in these tests.

The failure of these materials under field conditions was believed to be caused largely by the detoxification of the treated irrigation water as it percolated through the soil of the dikes thus inducing a dilution factor. Water in terraces flooded by subsurface seepage was found to be nontoxic to mosquitoes.

Small plot tests with granular formulations of Chlorthion, malathion, Dipterex, and DDVP applied as preflood applications at the rates of 0.2, 0.4, and 0.5 pound per acre failed to give satisfactory larval control. The same formulation of Chlorthion applied as a postflood treatment at the rate of 0.2 pound per acre gave essentially 100 percent control of larvae.

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See page 218 for notice of next annual meeting of the American Mosquito Control Association.

FIELD TESTS WITH FOUR PHOSPHORUS INSECTICIDES AGAINST SALT-MARSH MOSQUITOES IN FLORIDA

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DDT resistance in salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied) and *A. sollicitans* (Wlkr.), in Florida was first reported by Deonier *et al.* (1950). By the summer of 1955 DDT, BHC, and dieldrin were giving unsatisfactory control in the same districts that originally reported the failure of DDT. In the fall of 1955 Gahan *et al.* (1956) obtained excellent control of adults with malathion and of larvae with Bayer 21/199 in these areas.

The experiments herein reported were conducted in 1956 to evaluate aerial applications of four organic phosphorus compounds against salt-marsh mosquitoes. Malathion, Chlorthion, and Dipterex were tested as sprays against adults. These three materials and Bayer 21/199 were evaluated as larvicides applied in fuel oil solutions and attapulgite granules.

TESTS AGAINST ADULTS. Four of the plots treated for adult control were located in Pinellas County, two were in Indian River County, and 19 in Brevard County. The Pinellas plots each comprised 50 acres of salt marsh with mangrove and buttonwood coverage. The Indian River plots each included 170 acres of wooded area where trees and undergrowth formed a canopy. The Brevard plots, which varied in size from 50 to 100 acres, consisted of seven marshes covered with pickleweed and salt-marsh Bermuda grass and twelve 100-acre sections of citrus groves. The cover was more dense in the mangrove marshes and wooded areas than in the citrus groves. *Aedes sollicitans* was the predominant species in the open marshes but *A. taeniorhynchus* predominated in all other tests.

The malathion was used in a fuel oil solution, Dipterex in a water solution, and Chlorthion was dissolved in an auxiliary solvent, cyclohexanone, at a ratio of 1:4, and then mixed with fuel oil.

All sprays were dispersed at 3 or 4 quarts per acre from airplanes. The Pinellas plots were sprayed with a Piper Cub flying 45-foot swaths at 50 m.p.h. and an altitude of 50 feet. The Indian River and Brevard plots were treated with a Stearman plane. In the Indian River tests the pilot flew 125-foot swaths 75–100 feet high at 70 m.p.h., and in the Brevard tests 100-foot swaths 50–100 feet high at 85 m.p.h. All treatments were made between daybreak and 8 a.m. at wind velocities varying from less than 1 m.p.h. to occasional gusts up to 10 m.p.h. The flight lines were cross-wind of all test plots and marked with a flag attached to a bamboo pole.

The relative abundance of mosquitoes before and 3, 6, and 24 hours after treatment was determined from the number of mosquitoes landing per man per minute on two observers at 20 stations in each plot.

The results of these tests are shown in Table 1. The maximum reduction was usually observed after 6 hours, whereas the 24-hour counts showed the effect of infiltration from untreated areas. Since the infiltration was not uniform in all tests, only the results obtained after 6 hours will be discussed.

[1] The writers acknowledge the assistance of J. D. Ringdahl and C. L. Burroughs, and the cooperation of E. J. Beidler, Lee Wenner, and A. L. Lafferty, directors of mosquito control in Indian River, Brevard, and Pinellas Counties. Robert J. Geary and Farbenfabriken Bayer Aktiengesellschaft supplied the Bayer 21/199, the Chemagro Corporation the Chlorthion and Dipterex, and the American Cyanamid Company the malathion.

TABLE 1.—Control of adult salt-marsh mosquitoes with aerial sprays of three phosphorus insecticides.

County	Terrain	Dosage (pound/acre)	Date (1956)	Pretreatment Count [a]	Percent Reduction after— 3 hours	6 hours	24 hours
			Malathion				
Brevard	Citrus grove	0.5	Aug. 1	278	99+	100	92
		.25	2	104	72	91	63
			Oct. 4	362	99+	100	38
	Open marsh	.25	July 13	290	..	99+	59
Pinellas	Mangrove marsh	.25	8	287	..	64	54
		.1	8	183	..	70	50
Indian River	Wooded area	.1	25	80	..	23	8
Brevard	Citrus grove	.1	Oct. 24	86	86	99	78
	Open marsh	.1	Sept. 20	177	95	99+	0
			Oct. 2	466	99	93	85
			Chlorthion				
Brevard	Citrus grove	.5	Aug. 1	93	85	98	74
		.25	2	161	94	99	90
			Oct. 4	455	51	82	15
			24	124	61	96	84
	Open marsh	.25	July 13	364	..	96	61
Pinellas	Mangrove marsh	.25	8	114	..	56	58
		.1	8	218	..	83	18
Indian River	Wooded area	.1	25	47	..	22	0
Brevard	Open marsh	.1	Sept. 20	488	83	74	50
			Oct. 2	294	83	94	76
			Dipterex				
Brevard	Citrus grove	.5	Aug. 1	115	88	96	61
			Oct. 24	64	20	77	92
		.25	Aug. 2	87	5	63	60
			Oct. 4	470	3	25	6
	Open marsh	.1	Sept. 20	270	53	53	0

[a] Average per man per minute.

TABLE 2.—Control of salt-marsh mosquito larvae with aerial sprays of four phosphorus insecticides.

County	Dosage (pound/acre)	Date (1956)	Pretreatment Count [a]	Percent Reduction in 24 Hours
		Malathion		
Brevard	0.25	July 13	238	99
Pinellas	.25	8	304	89
	.1	8	102	78
		Chlorthion		
Brevard	.25	July 13	154	99+
Pinellas	.25	8	54	97
	.1	8	390	60
		Bayer 21/199		
Brevard	.25	July 22	67	92
		Dipterex		
Brevard	.25	July 22	87	93

[a] Average number of larvae per dip.

At dosages of 0.1 to 0.5 pound per acre malathion gave good control (more than 90 percent) in citrus groves and open marshes, and Chlorthion gave good control in these environments in five of seven tests. Neither insecticide gave good control in wooded areas or mangrove marshes. Dipterex at 0.5 pound per acre gave good control only in one of two tests in citrus groves.

TESTS WITH OIL SPRAYS AGAINST LARVAE. Tests were conducted on 25- to 60-acre salt marshes to compare malathion, Chlorthion, Bayer 21/199, and Dipterex in oil sprays against mixed populations of fourth-instar salt-marsh mosquito larvae. These test areas were in Brevard and Pinellas Counties. Applications were made with the same airplanes and at the same rate of dispersal as in the tests against adults.

Fuel oil was used as the solvent and carrier, but Chlorthion and Bayer 21/199 were first dissolved in trichloroethylene at ratios of 1:5 and 1:9, respectively, and Dipterex in cyclohexanone at 1:4.

The effectiveness of the treatments was determined by comparing the number of larvae collected in 50 dips the day before and 24 hours following treatment. Aerial applications of oil sprays frequently fail to give satisfactory control of salt-marsh mosquito larvae, owing to the loss of spray through impingement on vegetation. For this reason only the open portions of the treated marshes were inspected.

Results of these tests are presented in Table 2. All four larvicides gave good control at 0.25 pound per acre. Malathion and Chlorthion were not effective at 0.1 pound.

TESTS WITH GRANULES AGAINST LARVAE. Tests with granules were conducted on salt marshes in Indian River County against mixed populations of fourth-instar salt-marsh mosquito larvae. The granules were 16/30-mesh attapulgite carrying 5 and 2.5 percent of malathion, 5 and 2 percent of Chlorthion, 1 and 0.5 percent of Bayer 21/199, and 5 percent of Dipterex. Granules with 1 percent of BHC were used as a standard.

All applications were made with a Stearman airplane flying at 80 m.p.h. and an altitude of 25 to 50 feet. The plane was equipped with a cockpit tank duster adjusted to deliver 10 pounds of granules per acre on 30-foot swaths. Applications were made during the afternoons of August 23 and 24 with variable winds up to 15 m.p.h., and on September 12 in the early morning or late afternoon with wind velocities of 15 to 22 m.p.h. Effects of the wind were offset somewhat by flying at an altitude of 25 feet whenever possible. Good coverages were obtained on all plots, as evidenced by the number and pattern of the granules observed on the ground and in the water. The effectiveness of the treatments was based on the difference in 50 to 100 dipping counts

TABLE 3.—Effectiveness of aerial applications of several granulated insecticides against salt-marsh mosquito larvae.

Dosage (pound/acre)	Date (1956)	Pretreatment Count[a]	Percent Reduction in 24 Hours
	Bayer 21/199		
0.1	Aug. 23	48	97
		77	99
	Sept. 12	133	99+
.5	Aug. 24	54	99
	Chlorthion		
.5	Sept. 12	100	100
		231	99+
		44	97
.2	do.	24	79
	Malathion		
.5	Aug. 23	139	78
	24	114	64
	Sept. 12	95	99
.25	do.	140	99
	Aug. 24	201	81
	Dipterex		
.75[b]	Sept. 12	27	99+
.5	Aug. 23	159	79
	24	105	0
	BHC		
.1[c]	Sept. 12	73	45

[a] Average number of larvae per dip.
[b] 15 pounds of 5.0 percent granules per acre.
[c] Gamma isomer.

before and 24 hours after treatment. Counts were made in mangrove, pickleweed, and open marsh.

Results of these tests appear in Table 3. Bayer 21/199 gave good control at 0.1 and 0.05 pound, Chlorthion at 0.5 but not at 0.2 pound, and Dipterex at 0.75 but not 0.5 pound per acre. Malathion gave good control at 0.5 and 0.25 pound per acre in some tests but not in others. BHC failed to give good control at 0.1 pound of gamma isomer per acre.

Summary. Field tests were conducted with aerial applications of four organic-phosphorus compounds against resistant salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlkr.).

Against adults, oil sprays of malathion and Chlorthion gave more than 90 percent control at 0.1 pound per acre in grove or marsh areas, and less than 60 percent control at 0.25 pound in mangrove marshes. A water solution of Dipterex gave 77 to 96 percent control at 0.5 pound per acre in groves, but was less effective at lower concentrations. In tests against larvae, oil solutions of Bayer 21/199, Chlorthion, malathion, and Dipterex gave more than 90 percent control at 0.25 pound per acre. As granular larvicides Bayer 21/199 gave 97 to 99 percent control at 0.1 pound per acre; at 0.5 pound per acre Chlorthion gave 97 to 100 percent control, malathion 64 to 99 percent, and Dipterex 0 to 79 percent.

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Officers and Directors of the American Mosquito Control Association please note that the annual business meeting will be held at 10:00 a.m. on February 23 at the Willard Hotel in Washington, D. C.

AERIAL SPRAY TESTS WITH MALATHION, PYRETHRUM, AND ALLETHRIN AGAINST *AEDES TAENIORHYNCHUS* IN FLORIDA

A. NELSON DAVIS,[1] E. J. BEIDLER,[2] AND JAMES D. RINGDAHL[1]

Insecticide resistance in salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlkr.), in Florida was reported in 1950 by Deonier and coworkers, and King, and in 1951 and in 1952 by Keller and McDuffie. By the summer of 1955 resistance had increased to such a degree in some of the intensively treated portions of the State that satisfactory control was not obtained with DDT, BHC, or dieldrin. In that year malathion was found to be highly effective against resistant adults when tested in aerial sprays (Gahan *et al.*, 1956), and this organic phosphorus insecticide is now being used in several portions of Florida.

Ginsburg (1936) reported that thorough spraying of the ground and surrounding vegetation with pyrethrum emulsion gave some protection to outdoor gatherings of people. However, the use of pyrethrum against mosquitoes outdoors has been limited to small-scale treatments because other insecticides could be used more economically on a large scale.

Since resistance to the organic phosphorus compounds may develop, a series of tests were run in 1956 to compare pyrethrum and allethrin plus piperonyl butoxide with malathion[3] in airplane applications. These tests were conducted on 100-acre plots in Indian River County, Fla., against adults of *A. taeniorhynchus*. Fuel oil solutions of these materials were applied to wooded areas where trees and undergrowth formed a canopy that increased the problem of control. Three plots were sprayed on three dates with the three materials, and each plot received

TABLE 1.—Control of adult salt-marsh mosquitoes with aerial sprays.

Date Applied (1956)	Plot Treated	Pretreatment Count (average/man/minute)	Percent Reduction after: 3 hours	6 hours	24 hours
		Pyrethrins 0.1 percent plus piperonyl butoxide 0.5 percent			
August 7	B	42	6	28	..
30	A	52	85	78	0
September 5	C	98	58	61	21
		Allethrin 0.2 percent plus piperonyl butoxide 0.5 percent			
August 7	A	59	71	58	..
30	C	99	84	80	7
September 5	B	86	65	48	24
		Malathion 2.86 percent			
August 7	C	33	73	87	..
30	B	127	93	91	33
September 5	A	88	92	98	83

[1] Entomology Research Division, Agr. Res. Serv., U.S.D.A.

[2] Director of the Indian River Mosquito Control District.

[3] The pyrethrum and allethrin concentrates were furnished by the Fairfield Chemical Division, Food Machinery and Chemical Corporation, and the malathion by the American Cyanamid Company.

each material once to minimize the effect of differences between plots.

All applications were made with a Stearman (PT–17) airplane flying 80 m.p.h. at altitudes of 75 to 100 feet. This plane was calibrated to disperse 1 gallon of spray per acre with swath intervals of 125 feet. Applications were made between dawn and 7:20 a.m. under favorable meteorological conditions. Wind velocities varied from less than 1 m.p.h. to occasional gusts up to 7 m.p.h. The flight lines were cross-wind of all test plots. A cloth flag attached to the end of a 55-foot pole was utilized to mark each swath to insure uniform coverage. The mosquito populations were sampled before and after treatment by two observers at 20 counting stations in each plot. The stations were marked for the initial test and the same stations used for succeeding ones. Control was determined by comparing the number of mosquitoes per minute that landed on the observers on the day before and 3, 6, and 24 hours after applications.

The results of these tests are shown in Table 1. The sprays containing malathion were more effective than those containing synergized pyrethrins or allethrin. After 6 hours malathion gave an average reduction of 92 percent compared with 62 percent for allethrin and 56 percent for the pyrethrins formulations. A rapid infiltration of mosquitoes reduced the control obtained after 24 hours with all the insecticides. Better control would probably have been obtained in less densely foliated residential areas.

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14th Annual Meeting of the American Mosquito Control Association to be held in Washington, D. C. **See page 218 for further information.**

PROGRESS REPORT OF AN INVESTIGATION OF THE RELATIONSHIP OF WATER TABLE LEVEL FLUCTUATION TO MOSQUITO DEVELOPMENT AND POPULATION DENSITY, 1954–1956 [1]

F. R. DU CHANOIS AND L. B. ALLTOP [2, 3]

SUMMARY OF WATER TABLE LEVEL STUDIES, 1954–1955

TECHNIQUES. It is believed that one of the principal keys to successful mosquito control ultimately lies in a study and understanding of mosquito ecology. Hence, in January 1954, three 24 x 1 x 4 inch wood stakes (Nos. 1, 2 and 3) were placed at various locations on the U. S. Naval Air Station, Jacksonville, Florida, to determine the ground water table level fluctuation. These stakes proved to be unsatisfactory because the water table level was usually below the stakes and could not be recorded. They were discontinued.

In March 1954 at the south end of the station, a 60-inch diameter stump hole was deepened to about 50 inches and stake No. 3 was driven into the center. The elevation of the stake top was 23 feet 6¾ inches above mean sea level. It is from this stake that all of the significant recordings herein reported have been made.

Within ten feet of stake No. 3, a 100-inch long, hollow pipe (inside diameter 2 inches) was driven into the ground 70 inches in order to determine water table level with minimum rate of evaporation. In the spring of 1955 the actual elevation above mean sea level of both stakes and pipe were determined by engineering survey in order to have standard reproducible reference points.

FINDINGS. During a sixteen month period, this investigation has shown that by observing the water table level fluctuation, the following questions could be answered with a reasonable degree of satisfaction:

(1) Is there a relationship between the reading on the stake and the surface water level of actual or potential mosquito production habitats?

Yes. It has been observed that when the water level reading on the stake is 42 ± 2 inches, surface water will be found in all stump holes, marshes, swamps and ditches, both standing and running, and that mosquito larvae will be present in many of these habitats provided there is insufficient surface run-off and percolation to interrupt development through drying. Furthermore, it has been observed that when the stake water level reading is no higher than 27 inches, all stump holes and approximately 50 per cent of the marsh and swamp areas are dry. When the water level reading falls below the 27 inch mark, the remaining areas will rapidly become dry (i.e., free of standing surface water).

(2) Can a rough estimate of the daily evaporation rate be made and if so, can this be correlated with the length of time surface water will remain in certain mosquito production areas? What is the advantage of this?

The answer is thought to be—yes. Although the daily mean evaporation rate has not yet been established, work up to this point indicates that a reasonable estimate may be in the order of one inch per day at this station, provided, of course,

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[1] The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

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[3] Acknowledgment is gratefully made of the initiative and encouragement given by CDR K. L. Knight, MSC USN, in the pursuit of this study.

there is no rainfall. The advantage of knowing this is obvious in that it will enable field workers to estimate how long water will remain in certain areas and predict mosquito development, and to time probable adult emergence. For example, when the stake water level reading is 33 inches, it has been possible to estimate that all the stump holes would be dry in about six days; and consequently, larval control measures were obviated, since very little, if any, emergence of mosquitoes could occur.

(3) How can the stake water level reading be used to advantage?

By noting the stake reading accurately and regularly it is possible, in most cases, to know where the existing surface water is located. It will permit an estimate of the length of time the water will remain standing in any given area in the absence of additional rainfall. This informs the investigator or field surveyor where larviciding or further field survey reconnaissance may be required, if at all. In short, this information makes possible a greater accuracy in forecasting mosquito development, emergence and need for control measures.

Future Plans. Some of the problems that remained to be worked out were:

(1) All ditches, marshes, swamps and stump holes would have to be more accurately recorded and determinations made of that stake reading at which each would be dry.

(2) Daily mean evaporation rate would have to be determined together with standard deviations. Evaporation pans are presently being evaluated and an attempt made to correlate the evaporation rates of these with those of the stake site.

(3) Because of the fact that during some rains there is an unequal distribution of rainfall over the controlled area other stakes may have to be located at other points on the station.

The pipe described above has not yet been fully evaluated.

Conclusions, 1954–1955. It is believed that fluctuation of water table level has a definite relationship to the population density and other mosquito bionomics, the regular recording and tabulation of which may be a useful aid in forecasting brood emergence and scheduling control operations if indicated.

Summary of Water Table Level Studies, 1955–1956

Techniques. Observations and readings of the water table level have been made during the current mosquito season with some modifications as follows:

(1) Evaporation pans were found to be an unreliable index to surface water evaporation and were discontinued.

(2) The daily reading of instruments, such as stake or pipe used to determine water table level, also indicates the rate of evaporation. These daily readings are laborious and to obviate them it is hoped that the following equation, which is used to determine the amount of evaporation over a large water surface at sea level, may be used to determine the daily rate of evaporation without reference to the instruments:

$$E=(18 + 39.2 \times v^{0.75})\ (e_m - e);$$

where E = Evaporation in cc. per square meter of surface; v = Wind force (Beaufort's scale); e_m = Maximum vapor pressure at prevailing temperature in mm.; e = Actual vapor pressure in mm.

(3) In an effort to improve the method by which the fluctuation of the ground water table level is measured and recorded, a modified procedure for determining variations in the exposed water table within the pipe has been developed as follows:

A 130-inch length of one-inch inside diameter pipe is driven into the ground to a depth of 100 inches. A fishing cork float with a nylon thread attached to the upper end is dropped down inside the pipe to the water surface. The free end of the thread is strung over a pulley that is secured to a stake driven into the ground parallel to the pipe. An arbitrary graduated scale in inches and fractions of an inch is made from two yard-sticks placed

vertically end to end and attached to the stake. A pointer is attached to the thread along the scale so that changes in the water table level can be read in inches directly from the scale as the float moves up and down with the changing water level.

(4) Observation procedures for the water level readings in the pipe are still not entirely satisfactory. During the next year, two 4-inch inside diameter pipes located about 3½ miles apart will replace the smaller pipe. The addition of these should enable readings to be made with greater accuracy, using the float-pulley measuring device.

FINDINGS TO DATE. (1) It has been observed that when the water level reading on the stake is 42 ± 2 inches, surface water both standing and flowing will be found in all stump holes, marshes, swamps and ditches, and that mosquito larvae will be present in many of these habitats provided there is insufficient surface run-off and percolation to interrupt development through drying. Furthermore, it has been observed that when the water level reading on the stake is no higher than 27 inches all stump holes and approximately 50 percent of the marsh and swamp areas are found to be dry. When the water level reading falls below the 27-inch mark the remaining areas will rapidly become dry (i.e., free of standing surface water).

(2) Although the daily mean evaporation rate has not yet been established, work up to this point indicates that a reasonable daily average estimate may be in the order of one inch at this station, provided of course there is no rainfall. The advantage of knowing this, together with the water level, is obvious in that it will enable field workers to estimate how long water will remain in certain areas and predict mosquito development and probable adult emergence. For example, when the stake water level reading is 33 inches it has been possible to predict that all the stump holes would be dry in about six days. Consequently larval control measures were obviated since very little, if any, emergence occurred.

(3) By recording the stake reading accurately and regularly it is possible, in most cases, to know by and large where the existing surface water is located. This permits an estimate of the length of time water will remain standing in any given area in the absence of additional rainfall. This informs the inspector or field surveyor if and where larviciding or further field reconnaissance is required. In fine, this information makes possible a greater accuracy in forecasting mosquito development, emergence and need for control measures.

(4) A comparison of the water table level measurements and mosquito abundance for the past three years is given in Table 1. The measurements at stake No. 3 were taken at intervals during the nor-

TABLE 1.—A comparison of water table level recordings and overall mosquito prevalence during a three-year period, U. S. Naval Air Station, Jacksonville, Florida.

	Average Water Table Reading (Inches on stake)	Mosquitoes/ Trap/Day [1] (Average number)
	1954	
April	18.3	0.8
May	3.0	3.4
June	3.6	3.2
July	7.9	7.4
August	5.7	4.7
September	40.5	4.4
October	39.7	1.9
	1955	
April	35.0	6.6
May	9.8	8.1
June	8.1	7.5
July	18.8	13.7
August	12.4	11.1
September	39.8	32.5
October	49.5	27.7
	1956	
April	21.5	4.4
May	32.8	5.1
June	17.5	3.5
July	30.1	10.1
August	25.4	7.7
September	22.1	3.8
October	40.0	6.2

[1] Based on 8, 10, and 9 mosquito light traps for 1954, 1955 and 1956 respectively.

mal mosquito season (April–October). The average water level reading was computed for each month as well as the average number of mosquitoes per trap per day. These averages were computed statistically using rank correlation.

Unfortunately, analysis showed no correlation or negative correlation between the observed water level and the mosquito abundance for any of the years compared. Although these data appear to be in direct contrast to previously mentioned observations, many important factors which cannot be analyzed statistically must be taken into consideration. Some of these factors are: wind, unequal distribution of rainfall over the observed area, adulticiding by ground and air, larviciding and permanent control measures. Taking these factors into account, field observations reasonably show that there is a correlation between the water level and prevalence of mosquitoes during April through October when temperature and rainfall are most ideal for their aquatic development.

Future Plans and Problems to Solve. Some of the problems which remain to be worked out are:

(1) Several years' additional data will be needed to make accurate comparisons between the stake readings (water table) and the surface water level in ditches, marshes, swamps and stump holes. This will be accomplished by simultaneously observing the stake readings and water level in ditches, marshes, swamps, and stump holes within a given area.

(2) At present it is difficult to obtain fine readings from the stake to determine water level fluctuations of less than one-half inch. It is expected that readings obtained from the 4-inch pipes will produce greater accuracy.

(3) Lack of additional pipes has prevented sufficient observations on the effect of unequal distribution of rainfall over the station. The addition of two 4-inch pipes, located about 3½ miles apart will partially overcome this deficiency.

(4) A field sampling method has not yet been developed which can be used to establish the relationship between larval indices and the water table level over an exact observation area.

Summary. Progress is reported on an investigation to determine the relationship of the water table level to the production and density of larval and adult mosquitoes at the Naval Air Station, Jacksonville, Florida. The development and refinement of techniques used to measure the water table level and evaporation rates are described. Use is made of the readings of water level from stakes and pipes in an attempt to correlate this with mosquito population abundance based on light trap indices. A working relationship is established between these readings and actual or potential mosquito production capacity of certain habitat sources. It is concluded that the techniques when properly developed may have value in prognosticating brood emergence and scheduling of control operations if indicated.

A PROGRESS REPORT ON DOSAGE TESTS WITH MOSQUITO ADULTICIDES

ANDREW J. ROGERS,[1] E. J. BEIDLER,[2] AND CARLISLE B. RATHBURN, JR.[3]

This paper presents a discussion of what is believed to be a new concept of dosage with aerosols applied under field conditions and a progress report on insecticide dosage tests with aerosols against adult salt-marsh mosquitoes in Florida.

CALCULATING DOSAGE WITH AEROSOLS. Collins (1955) summed up the complex problem of dosage with aerosols when he stated ". . . We are still hazy as to what we mean by dosage when we speak of fogs. Many of us regard the expression of so many pounds or gallons per acre as out of place in referring to fogs or mists. The expression is especially meaningless with respect to fog."

The following discussion of this subject presents a method of calculating dosage with out-door aerosols which is believed to be sound from the standpoint of the established principles of insect control by chemicals, and which will permit a more accurate expression of dosage than other methods in use.

The pounds-per-acre method of expressing insecticide dosage appears to have more real significance in relation to insect control under field conditions than other methods. This concept has largely replaced the "per cent-concentration" method in control of agricultural pests. A certain amount of toxicant per given area is required to give control of insects under field conditions. Therefore it usually makes little difference whether the insecticide is applied as a 1 percent spray or a 10 percent spray, provided the required amount of insecticide is applied and adequate coverage is obtained.

This same sound principle of dosage can be applied to the control of adult mosquitoes with aerosols, but the calculation must be different from that used in control of agricultural pests. For example, a modern aerosol operation using 7½ percent DDT at 40 gallons per hour, 5 m.p.h., would release 8 gallons containing 5 pounds of DDT along one mile of front. If an arbitrary swath of 900 feet is assumed, the treated plot would contain 109 acres. The usual procedure in calculating the dosage in this example is to divide 5 pounds by 109 acres—dosage .05 lb. per acre.

Since this method assumes an equal distribution or deposit of insecticide on each acre, this may be termed the "deposit" method of calculating dosage. This concept of dosage is correct for use with coarse sprays to control plant pests, but it does not meet the requirements for aerosol applications. There are several reasons for this: 1. Aerosols drift horizontally and do not deposit in the same manner as do coarse sprays. 2. Aerosols are primarily space sprays, meaning that they treat the space above the soil. In terms of acres, this may be visualized as the cubic volume of air above an acre of soil through which the aerosol cloud passes. 3. The insecticide in an aerosol which treats the space above an acre of soil is of more importance in killing adult mosquitoes, or other flying insects, than the very small quantity which deposits on the soil or plants.

Yeomans' paper on directions for applying wind-borne aerosols was concerned primarily with deposits from aerosols to control agricultural pests (Yeomans, 1950). However, Yeomans' paper contains data which may be used to calculate correctly in pounds per acre the dosage when applied as an aerosol to control adult mosquitoes. This may be called the "space" method of calculating dosage to distinguish it from the "deposit" method

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TABLE 1.—(After Yeomans, 1950) Effect of particle size on the percent of total insecticide depositing on 100-foot strips across a field. (Wind 3 m.p.h.)

Distance from Release front (feet)	Percent Deposit in Each 100-ft. Section	
	40 micron m.m.d.	25 micron m.m.d.
0–100	7.6	1.4
100–200	7.5	1.4
200–300	6.5	1.4
300–400	4.7	1.4
400–500	2.8	1.4
500–600	1.8	1.4
600–700	1.7	1.4
700–800	1.7	1.0
800–900	1.7	0.7
Totals	36.0	11.5

already described. Yeomans' data on deposits from aerosols are reproduced in part in Table 1.

Data in Table 1 show that in a 3 m.p.h. wind, 88.5 percent of the insecticide in an aerosol of 25 microns mass median diameter is still air-borne at 900 feet, and 64 percent is still air-borne at this distance when the mmd is 40 microns. Based upon the 40-micron data in Table 1, the correct calculation of the dosage in pounds per acre for the 7½ percent DDT example previously cited would be as shown in Figure 1.

Data in Figure 1 show that the first 100-foot strip of the 109-acre plot would receive a dosage of .412 lb. per acre. Deducting the 7.6 percent (see Table 1) of insecticide that deposits on the first 100-foot strip, the dosage for the second 100-foot strip is .381 lb. per acre, etc., etc. This dosage takes into account both the amount of insecticide that deposits on the soil and the amount that treats the air above the 12.12 acres of each strip. Thus the true average dosage in pounds per acre in the theoretical example is .321 lb. instead of .05 lb.

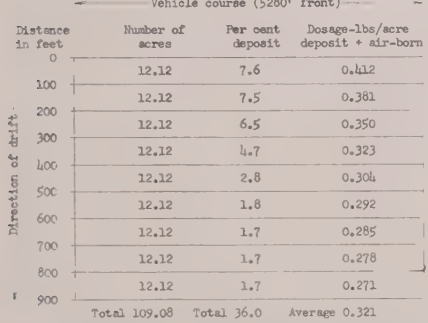

FIG. 1.—"Space" method for calculation of dosage with wind-borne aerosols.

This principle is graphically represented in Figure 2, which shows the dosage curves for the equal distribution or "deposit" method compared with the "space" method corrected to two droplet sizes.

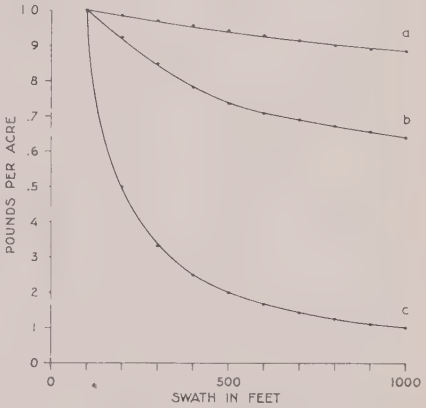

FIG. 2.—Comparison of dosage curves: a. Corrected to 25μ mmd; b. Corrected to 40μ mmd; c. Equal Distribution.

Thus, using the "deposit" method of calculating dosage, the dosage in pounds per acre is reduced by one-half as the swath width is doubled. This would indicate a substantial decrease in mortality with an increase in distance. However, good kills in these tests were obtained at a distance of 660 feet, and with the better dosages, kills of 90 percent and better were obtained at a distance of 1,320 feet. As may be seen from the distance-mortality curves (Figure 3), the kill at increased swath widths falls off only slowly, giving a curve that is more comparable to that of

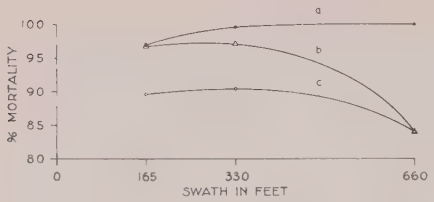

FIG. 3.—Distance-mortality curves: a. 0.54 lbs./a. malathion; b. 0.13 lbs./a. malathion plus 3% v/v Lethane 384; c. 0.27 lbs./a. malathion.

the corrected curves (based on Yeomans' data) than that of the equal distribution curve c of Figure 2.

An important aspect of these two concepts of dosage with aerosols is the effect they may have on the interpretation of data already published. For example, in a frequently cited paper, Brescia (1946) recommended as an aerosol 15 gallons per 1,000 front feet of DDT emulsion containing .3235 lb. DDT per gallon. Brescia concluded that this dosage would control adult salt-marsh mosquitoes up to one mile down wind in open country. Converting Brescia's operation of pounds per acre by the "deposit" method, the dosage was .04 lb. per acre; but calculated by the "space" method, Brescia's dosage was approximately 2.00 lbs. per acre.

Although Brescia did not state this himself, it could be concluded by using the "deposit" method of calculating dosage that a modern aerosol generator discharging 5 percent DDT at 20 gallons per hour would apply the same dosage in pounds per acre over a swath of one city block (330 feet) as Brescia applied per acre over a swath of one mile. However, calculated by the "space" method, and assuming a wind velocity of three miles per hour, Brescia's dosage over the first 330 feet of his swath was 2.08 lbs. per acre and the modern machine in this comparison applies only .14 lb. per acre over the same swath. Therefore Brescia's operation in terms of dosage was equal to 15 of the modern machines moving en masse down the same street at five miles per hour and applying 5 percent DDT at 20 gallons per hour over a swath of one city block (330 feet).

In terms of one small-capacity modern aerosol generator discharging 40 gallons per hour at 5 miles per hour, the single generator in order to equal Brescia's true dosage in pounds per acre would be required to use a concentration of approximately 40 percent DDT (w/v).

It is not intended to imply by these comparative statistics that small-capacity generators cannot be used effectively in controlling adult mosquitoes. But the figures do illustrate the fallacy of computing dosage with outdoor aerosols by the "deposit" method. Also, these figures seem to justify a re-evaluation of existing dosage recommendations for small-capacity aerosol generators.

RESULTS OF DOSAGE TESTS. Using the cage-test technique described in another paper by the same authors in this issue of *Mosquito News*, dosage tests with various insecticides against adult salt-marsh mosquitoes were conducted at Vero Beach, Florida, from September 1956 to April 1957.

These tests were all made with a Tifa aerosol machine operated at 1,000° F., formulation pressure of 25 p.s.i., 40 gallon per hour discharge, and vehicle speed of five miles per hour. Number 2 diesel oil was the basic diluent used in all formulations. The testing time was from about 8:00 p.m. to 11:00 p.m. under good conditions of inversion and wind velocities ranging from 1 to 10 m.p.h.

Based upon 12-hour mortality of female mosquitoes, the results of these tests are shown in Table 2.

DISCUSSION. The data show that malathion was by far the most effective insecticide used in these tests at the dosage levels indicated. Unfortunately, interpretation of dosage with DDT against Florida salt-marsh mosquitoes is clouded by the resistance factor. However, based upon the "space" method of computing dosage and upon findings and recommendations like those of Provost's (1952), it seems reason-

TABLE 2.—Results of dosage tests with aerosols against *Aedes taeniorhynchus* and *Aedes sollicitans* in screened cages under field conditions, 1956–57.

Insecticide	Formulation lbs./gal.	Formulation % v/v	Average Dosage in lbs./acre [1]	Number of Replications	Percent Kill (660 foot swath) [2] Average	Percent Kill (660 foot swath) [2] Range
Malathion	1.00	...	0.54	3	99	95–100
Malathion + Lethane 384	0.25	... 3.0	0.13	3	92	87–96
Malathion	0.50	...	0.27	18	88	60–100
Malathion + Thanite	0.25	... 3.0	0.13	3	74	72–77
Malathion	0.25	...	0.13	3	60	49–65
Lethane 384	....	5.0	....	2	41	30–47
DDT	1.00	...	0.54	5	30	15–58
Cubetoid	....	10.0	....	3	30	23–38
Lethane 384 special	....	10.0	....	3	30	28–37
Thanite	....	5.0	....	3	23	17–35
Pyrethrum + Piper. butoxide	....	0.06 0.3	....	3	17	15–22
DDT + Thanite	0.625	... 3.0	0.10	3	10	7–14

[1] Average dosage over a 660-foot swath considering both deposit and treatment of space above the soil.

[2] Data corrected to check mortalities using a modification of Abbott's formula by Sun and Shepard.

able to assume that there has been considerable underdosing with DDT in aerosol generators.

Dosage levels in these tests with Lethane, Thanite, and Cubetoid Extract were based upon label recommendations or upon dosage levels most frequently used in control operations with thermal aerosols. The pyrethrum-piperonyl butoxide dosage was based upon costs that were comparable with malathion at 0.5 lb. per gallon.

With the exception of Lethane 384 in combination with malathion, the results with all of these materials were unsatisfactory at the dosage levels used.

Malathion at 0.5 lb. per gallon was used as a standard in most of the tests, which accounts for the large number of replications with this formulation. In the 18 replications with this dosage of malathion, *Aedes sollicitans* comprised only 5 percent of 3,339 mosquitoes used, but the kill was the same as for *Aedes taeniorhynchus,* namely, 88 percent.

Dosage levels reported on in this paper have been tested to date only in open terrain and with the Tifa aerosol generator. Therefore it is not intended to imply that the same results would be assured under various conditions of terrain and with other kinds of aerosol equipment.

These tests were conducted during the season of the year (September to April) when minimum temperatures prevail in

Florida; the maximum temperature during the tests was 76.5° F. and the minimum was 56.5°.

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A CAGE TEST FOR EVALUATING MOSQUITO ADULTICIDES UNDER FIELD CONDITIONS

ANDREW J. ROGERS,[1] E. J. BEIDLER,[2] AND CARLISLE B. RATHBURN, JR.[3]

During 1956, the Entomological Research Center of the Florida State Board of Health, working in cooperation with the Indian River Mosquito Control District, initiated a comprehensive research program to gain information on the most efficient use of equipment and insecticides in the mosquito adulticiding program in Florida.

Some of the equipment and techniques are similar to those used by many research agencies. Certain other procedures are believed to be different from previously published methods.

In selecting a procedure for adulticide studies, it was felt that each major facet of the overall problem could best be handled as a separate experiment. This procedure should reduce confounding of results by eliminating the necessity of trying to evaluate many different problems from a single set of data.

Information on effective dosage of various insecticides, some old and some new, was selected as the most critical need in the Florida adulticiding program. This paper presents the methods that have been developed for these dosage tests to date.

Although Brescia (1946), Clark (1947), Horsfall (1950) and others have demonstrated that mosquitoes in screen cages can be killed with aerosols, the landing rate method of evaluating dosage has been more widely used under field conditions. It was felt that caged mosquitoes would allow a more accurate evaluation of dosage levels under the conditions of these tests.

METHODS. *Rearing and Handling Test Insects.* When available, the larvae and pupae of the salt-marsh *Aedes* are collected in natural breeding areas and reared to the adult stage in the laboratory. When larvae or pupae are not available in the field, sods are brought to the laboratory and flooded to hatch the eggs. Fifty pupae are placed in a pint Mason jar filled with tap water. On the top of each jar is mounted with masking tape a 14 by 18 mesh screen cage, six inches high and the same diameter as the inside of the standard Mason jar cap, which is used as a top; see Fig. 1(1). An inverted paper funnel is fitted into the open end of the cage with two small pieces

[1] Entomological Research Center, Florida State Board of Health.

[2] Director, Indian River Mosquito Control District.

[3] Entomological Research Center, Florida State Board of Health.

of tape. The funnel, which is made by cutting the tip from cone-shaped drinking cups prevents the mosquitoes from returning to the water, where many specimens would become caught in the surface film.

The adults are allowed to emerge into the cage during 48 hours, then the cages are taken from the jars, the paper funnel is removed, and the open end of the cage is closed with a friction-fitting screen cap, Fig. 1(2). At the time the cage is removed from the emergence jar, a pad of cotton saturated with sugar water is placed on the screened top; the pad is moistened daily with tap water. Test insects are all between the ages of two and eight days, and, when possible, all mosquitoes used in a single night's testing are of the same age.

No attempt is made to separate the two species of salt-marsh mosquitoes in the cages, but test mortality statistics are recorded separately for each species. Male mosquitoes are also left in the cages, but because of the higher natural mortality rate of the males, only female mosquitoes are used in mortality counts.

Test Procedure. The test area is an undeveloped subdivision where there are good dirt roads and a minimum number of trees and tall shrubs. Stations are permanently marked along streets at 165, 330, and 660-foot intervals in the four compass directions. This system allows fast preparation for testing regardless of wind direction. The station distances correspond to one-half, one, and two average city blocks respectively.

Two cages of mosquitoes are suspended horizontally by means of small-gauge copper wires from heavy-gauge wire "arms" which are attached to one inch by two inch by six foot wooden stakes (Fig. 2). One cage is two feet and the other cage six feet above the ground. Stakes are provided with a pointed, strap iron spike, which facilitates their mounting in the ground without driving.

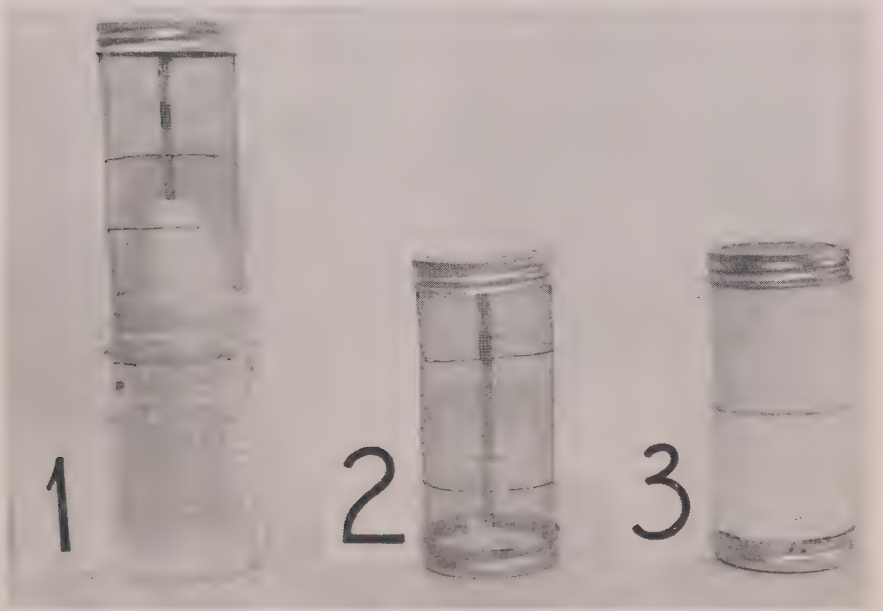

Fig. 1.—1. Emergence jar with cage mounted on top; 2. Caged mosquitoes with cotton pad on top; 3. Clean cage.

FIG. 2.—Stake with cages attached as in field test.

Each test or replicate consists of the cages from two sets of stakes, or a total of twelve cages. In almost all tests to date, four cages of mosquitoes picked at random from the test group and placed in a similar manner in another subdivision about two miles away have served as checks for the tests.

Cages are exposed to the test insecticide in the usual manner of driving the fogging vehicle along the upwind side of the plots. Starting ten minutes after the test begins, the treated mosquitoes are transferred to clean cages at the stake and cages of untreated mosquitoes are hung on the stake for the next test.

The technique for transferring treated mosquitoes to clean cages is similar to a procedure used by the Orlando, Florida laboratory of the U. S. Department of Agriculture. The treated cage is tapped several times on a horizontal surface to force the mosquitoes to the bottom of the cage. The loosened top is then quickly pushed off by an upswing of the clean cage, which is held bottom up in the opposite hand; this motion is completed by bringing the open end of the clean cage into position over the open end of the treated cage. The positions of the two cages are then reversed and the mosquitoes are forced to the bottom of the clean cage by tapping it several times on the horizontal surface. Before the mosquitoes can recover, the treated cage is flipped off and the top is placed on the clean cage. The entire process can be completed in 5 to 10 seconds. The clean cages are wrapped with a paper towel held in place by a rubber band, Fig. 1(3). This is to reduce chances of contamination from the operators' hands. Also, a number 6–6 Lily paper cup lid is placed in the bottom of the cage to facilitate counting the mosquitoes.

Three experienced workers can transfer the twelve cages of treated mosquitoes to clean cages and prepare the next group for testing in a period of about 10 minutes.

Wind velocities are recorded with a cup anemometer at six feet above the ground during each of the three minutes required to treat a replication. The temperature at six inches and at six feet above the ground, and the relative humidity are also recorded for each replication as a routine procedure. Soap bubbles have proved helpful in ascertaining wind direction and behavior in connection with the tests.

Treated insects and checks are held for 12 hours, out-of-doors, protected from rain, and then examined for mortality. A mosquito that is able to fly is counted as being alive. All cages, including the checks, are cleaned with an acetone-water-acetone wash after each test.

EVALUATION OF TEST. Although laboratory precision cannot be expected in a field test, especially with problems presenting as many variables as do wind-borne aerosols, the data obtained in these cage tests have been very satisfactory. The reproducibility of results, especially with the more effective dosage levels, has been excellent. Data from 18 replications with the same dosage of malathion show a coefficient of variation of only 12.5 percent and a standard deviation of 2.59.

The accuracy of the test is also supported by a straight-line dosage mortality curve with three dosage levels of malathion, Fig. 3. The average percent kills with their corresponding dosages are 60.0 percent at 0.13 pound per acre, 88.1 percent with 0.27 pound per acre and 98.8 percent at 0.54 pound per acre. The 0.27 pound per acre dosage represents 18 replications, the other two dosages three replications each.

The effectiveness of the technique used in rearing and handling the test insects is supported by data from check mortalities. A total of 34 replications averaging 58 female mosquitoes per replication, show an average mortality of only 1.1 percent with a range of 0 to 5.7 percent. Although corrected data based upon check mortalities are used, they are so similar to the uncorrected data that little is gained by the corrections.

EXPERIMENTAL DESIGN. The test is easily adaptable to the randomized blocks design, using time as blocks and randomizing treatments within blocks. This design has the advantage of allowing any treatment to be dropped at any time without affecting other treatments or the statistical analysis of the data. However, due to weather variations, etc. between the blocks, larger differences between treatment results may be necessary to show significance if the treatments are too numerous to be run on a single night.

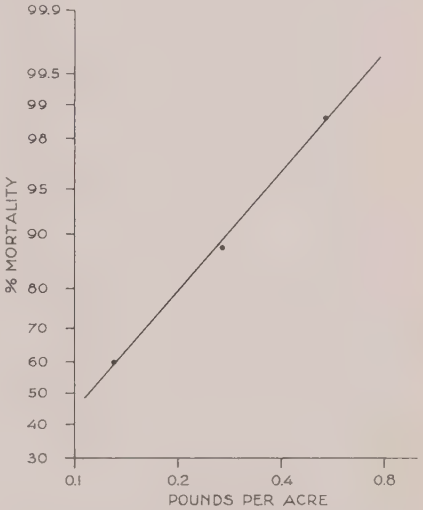

FIG. 3.—Dosage-mortality curve based upon three dosage levels of malathion.

DISCUSSION. Using a screen bottom instead of a solid bottom on test cages might improve the technique by allowing maximum chance for coverage inside the cage.

Although the test has been used only for dosage experiments with mosquito adulticides, it probably can be utilized in swath determination and similar problems.

Also, it appears to have potential utility in field testing insecticides against other insects, such as black flies and house flies.

The test has been evaluated only with thermal aerosols, therefore its usefulness in testing other methods of application is not known at this time.

ACKNOWLEDGMENTS. The authors are indebted to Dr. Erik Nielson and Dr. M. W. Provost of the Entomological Research Center, Florida State Board of Health for their assistance and helpful suggestions relative to meteorological instruments and certain procedures used in these tests.

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FURTHER STUDIES WITH WATER-SOLUBLE INSECTICIDES FOR THE CONTROL OF MOSQUITO LARVAE IN IRRIGATION WATER

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Entomology Research Division, Agr. Res. Serv., U.S.D.A.

Previous tests by Gahan and Mulhern (1955) and Gahan and Noe (1955) demonstrated that water solutions of Dipterex (Bayer L 13/59), Phosdrin (Shell OS–2046), and parathion were effective against floodwater *Aedes* and *Psorophora* spp. in irrigation water. In California pastures Dipterex and Phosdrin at concentrations as low as 1 p.p.m. gave 99.9 to 100 percent control. Incomplete control was obtained with Dipterex at 0.1 p.p.m. In Arkansas rice fields 100 percent control was obtained at 0.5 p.p.m. with Dipterex, 0.25 p.p.m. with Phosdrin, and 0.01–0.02 p.p.m. with a solubilized parathion formulation. The greatest distance the chemically treated water was followed in California was ½ mile through fields, but in Arkansas it eliminated all *Psorophora* spp. in 10- to 17-acre blocks of rice after moving from 0.5 to 1.3 miles in a canal and as much as 2,500 feet through fields. None of the treatments had sufficient residual toxicity to be effective against *Anopheles* or *Culex* spp. after 1 week.

This study was continued in California pastures during May 1956 and in Arkansas rice fields during July and August 1956. Solubilized parathion was the only material studied in California, but all three materials were used in Arkansas. Chief emphasis was placed on determining the greatest distance treated water would flow across fields before it failed to cause 100 percent control.

In California the parathion was introduced inside standpipes into water that was being pumped from underground wells with large electric pumps. The treated

[1] R. F. Peters and T. D. Mulhern, of the California Department of Public Health, Bureau of Vector Control, assisted in making arrangements for the conduct of the California study, and J. R. Holten, of the Bureau of Vector Control, and E. Nottingham, of the Entomology Research Division, performed some of the routine duties. The Chemagro Company supplied the Dipterex, the Shell Development Company the Phosdrin, and the American Cyanamid Company the parathion.

water flowed from the standpipes into ditches that ran across the heads of the fields, and then was transferred to the fields through metal siphons. The area between two longitudinal levees that ran the full length of the field was included in each test. Twenty-four hours were required for flooding. The pH readings varied between 7.5 and 8.5 at various points along the water route.

Some of the treatments in Arkansas rice fields were also applied where large electric, Diesel, or gasoline pumps were emptying water from underground wells into pools, but others were added at some constricted point along the route of the irrigation water as it flowed between these pools and the fields. All the insecticides except Phosdrin passed through canals ranging in length from ⅛ to ¾ mile before entering the fields through cuts made in the canal banks. Phosdrin was introduced into a pool that adjoined the field. The rice plots treated ranged in size from 10 to 30 acres.

As in the 1955 tests, the chemicals were added to the irrigation water on a parts-per-million basis with the automatic applicator described by Gahan *et al.* (1955). Dipterex and Phosdrin were placed in the reservoir of the applicator as water solutions, but the parathion was used as a solubilized concentrate containing 1 part of parathion, 4 parts of Triton X-100, and water. The flow rate from all pumps was calibrated in gallons of water per minute, and the insecticide concentration in the reservoir was adjusted to obtain the desired dosage when the applicator was releasing 56 ml. of liquid per minute.

Effectiveness of the treatments was determined by dipping for larvae in treated and untreated plots on the first and second days after flooding. In the California tests, 200 dips were made in each plot. The number made in rice fields varied from 700 to 2,000 per field, depending on the acreage being treated. Examinations were made at 10- to 20-yard intervals until all sections of the field had been sampled. The density of larvae in two untreated rice fields was used for comparative purposes.

California Tests. Introductions of solubilized parathion into irrigation water being applied to the California pastures successfully eliminated all *Aedes* spp. breeding for distances as long as ⅜ mile, but gave complete control in only one field. Treatments at concentrations of 0.01, 0.02, and 0.05 p.p.m. killed all the larvae in 24 to 48 hours for ¼ mile, but 2 to 60 percent of those in the second ¼ mile survived. An application at 0.075 p.p.m. used in a field ⅜ mile long caused total mortality. Another at 0.1 p.p.m. caused above 99 percent kill for ⅜ mile but only 81 percent in the next eighth. At 0.005 p.p.m. parathion was completely effective for less than ⅛ mile, and no control was indicated beyond that point. (Table 1.)

Larvae were collected from untreated fields and introduced into water removed from fields treated with parathion at 0.05, 0.075, and 0.1 p.p.m. while irrigation was in progress. All died in 1 to 2 hours in water samples taken near the top of the plots and in 2 to 3 hours in others gathered from the middle. Samples from the lower end of the field treated at 0.075 p.p.m. caused 100 percent mortality in 3 hours, but those from the other two caused no knockdown in 24 hours.

Arkansas Tests. In rice fields larvae were eliminated completely from areas of 10 and 30 acres with parathion at 0.05 p.p.m., 20 acres with Dipterex at 0.5 p.p.m., and 5 acres with Phosdrin at 0.25 p.p.m. The maximum distance the treated water moved through the field before any larvae survived 48 hours of flooding varied from approximately ¼ mile for the parathion, 1.8 miles for Dipterex, and at least ½ mile for Phosdrin. The only treatment that gave complete control over an entire field was parathion on the 10-acre plot. Owing to failure of the pump, introduction of this insecticide was discontinued in the other field after 30 acres had been covered. In the remaining 21 acres of the field treated with Dipterex, the larval density averaged 0.09 per dip,

TABLE 1.—Control of *Aedes* larvae in California pastures with solubilized parathion.

Concentration of Parathion (p.p.m.)	Length of Field (miles)	Section of Field Examined	Percent Control
0.005	0.5	Upper and lower halves	0
.01	.5	Upper half	100
		Lower half	80
.02	.5	Upper half	100
		Lower half	40
.05	.5	Upper half	100
		Lower half	98.7
.075	.375	Upper and lower halves	100
.1	.5	First quarter	100
		Second quarter	100
		Third quarter	99.7
		Fourth quarter	81

whereas two untreated fields in the same general area averaged 4.5 and 10 per dip. The total distance traversed by the Dipterex was approximately 3 miles. In the second 5 acres of the field flooded with Phosdrin, the larval density averaged 0.25 per dip in the low part where the water eventually became at least 12 inches deep, but on the high areas, where the water depth never exceeded 4 inches, the average was 5.12 per dip.

DISCUSSION. Factors other than solubility of the chemicals in water obviously control the distance the treatments remain effective. Water solutions of Dipterex and parathion do not hydrolyze rapidly under normal conditions, for they have been stored in the laboratory for 20 weeks without losing their effectiveness (Gahan *et al.*, 1955). Yet under field conditions parathion lost much of its toxicity in less than 1 day and Dipterex failed to give complete control within 5 days. The tests conducted in 1955 by Gahan and Noe showed clearly that the toxicity of these two materials was not destroyed while moving 0.5 to 1.3 miles through canals. Also in all the field tests that have been conducted with Dipterex at 0.5 or 1 p.p.m., parathion at 0.01 or 0.02 p.p.m., and Phosdrin at 0.25 or 0.5 p.p.m., the insecticides were highly toxic when the treated water entered the field.

The greatest loss in effectiveness apparently occurred as the water moved across the field. In low areas of the pastures where the water became deep, larvae were seldom collected even at the foot of the field. They were most numerous in areas where the water was shallow. In rice fields the highest densities occurred close to the levees or on high parts of the field. Water that had seeped through the levees was never highly effective, even at distances less than 200 feet from the applicator. Larvae were always found breeding in this seepage and averaged as many as 12 per dip outside the borders of one field. Many of them were killed later on portions of the fields that were flooded intentionally. Larvae found outside the borders were not included in the evaluation of the treatments.

Adsorption of the chemical onto soil particles is the most obvious explanation for this loss in effectiveness. Other factors that may have some adverse effect are high water temperature, aeration, or pH. Any shortening of the distance the treated water must trickle across the fields in a shallow stream, by extension of the canal system, should be of assistance in reducing the importance of these factors. The water level in the canals can be maintained at sufficient depths so that a rapid flow

occurs and the insecticidal particles contact the soil less frequently.

SUMMARY. Introductions of solubilized parathion at concentrations of 0.01 to 0.1 p.p.m. into irrigation water being applied to California pastures eliminated all *Aedes* spp. breeding for distances as long as ⅜ mile, but survivors were found in the lower parts of all fields except one. A gradual loss in toxicity as the treated water moved across the field was indicated in tests conducted in samples removed from the top, middle, and lower portions of the test plots.

Psorophora larvae breeding in Arkansas rice fields were eliminated completely from areas as large as 10 to 30 acres with parathion at 0.05 p.p.m., 20 acres with Dipterex at 0.5 p.p.m., and 5 acres with Phosdrin at 0.25 p.p.m. The maximum distance the treated water moved through the field before any larvae survived was approximately ¼ mile for parathion, 1.8 miles for Dipterex, and at least ½ mile for Phosdrin.

Factors other than solubility of the chemical in water obviously control the distance the treatments remain effective. Adsorption of the chemical onto soil particles is believed to be important. High water temperature, aeration, or pH may also have some adverse effect.

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ARTICLES

THE DISPERSAL CHARACTERISTICS OF THE SALT-MARSH MOSQUITO, *AEDES TAENIORHYNCHUS* (WIEDEMANN), NEAR SAVANNAH, GEORGIA [1]

W. L. BIDLINGMAYER AND H. F. SCHOOF

INTRODUCTION. Despite the economic significance of the salt-marsh mosquitoes *Aedes taeniorhynchus* (Wiedemann) and *Aedes sollicitans* (Walker) in the coastal communities of the southern and eastern United States, much information is lacking on the biology of the two species. In an attempt to clarify the dispersal habits of these two species of salt-marsh mosquitoes, studies of this type were conducted in the vicinity of Savannah, Georgia, during 1954.

In this coastal area, *A. taeniorhynchus* outnumbers *A. sollicitans* but the latter species is more aggressive in attacking humans. The breeding grounds for these mosquitoes lie in the salt-marsh areas which extend northeast, east, and south of Savannah. The coastline near Savannah consists of a string of barrier islands separated from the mainland by 4 to 20 miles of saltmarsh. The continuity of the latter is broken by numerous islands and tidal creeks. The principal sites of mosquito production are at the higher marsh levels in association with saltgrass *Distichlis spicata* (L.) Greene.

METHODS: A. PRODUCTION AND MARKING OF THE MOSQUITOES

To provide a suitable and readily accessible breeding site, an area of saltmarsh (0.5 acre) was selected on Oatland Island 0.5 mile from the laboratory. This marsh site was surrounded on three sides by pine-covered upland; the fourth side was a road embankment which separated the study site from the main saltmarsh. The site was not a natural mosquito breeding area since, although subject to tidal action, its slope permitted the water to run off. To facilitate the handling of the mosquito larvae, the principal plant of the area, *Juncus roemerianus* Scheele, was cut and removed. As a means of regulating the tidal flow into the study site, a concrete dam equipped with flash boards was constructed over the inward end of the culvert which connected the study site with the main marsh.

The required mosquitoes were obtained by collecting mosquito-egg-infested sod samples or by inducing captive female adult mosquitoes to oviposit on soil media. Flooded random sod samples from an area of *Paspalum vaginatum* Swartz, indicated that that locale had a mosquito infestation rate of more than 1,000 eggs per square foot. Approximately 86 percent of the mosquitoes produced were *Aedes taeniorhynchus*. For the test, more than 2,000 square feet of *Paspalum* sod were transported to the study site.

Since *A. sollicitans* represented only 14 percent of the mosquitoes on the sod samples, 11,000 females of this species were captured by hand aspiration and caged. Moist soil was placed in the cage and a rabbit was furnished to provide a blood meal. No estimate of the number of eggs produced in this manner is known since preliminary studies gave erratic results with oviposition of from 4 to 100 eggs per female.

All soil samples were placed in the study site in August, the tidal waters being

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

allowed to enter the area on the night of August 15. On the following day it was apparent that a high percentage of the eggs had hatched. On August 18, 100 pounds of ground laboratory chow was broadcast over the pond to bolster the larval food supply. By the morning of August 19, many of the larvae were in the third instar of development and ready for transfer to the marking trays. Removal of the larvae was accomplished by dip nets, the specimens being crowded into six paraffined wooden trays ($4' \times 6' \times 0.5'$) filled with 4 inches of water. All trays were housed in a pyramidal tent erected adjacent to the breeding area.

To each of these trays radioactive phosphorus as $H_3P^{32}O_4$ was added at a rate of 50 microcuries per liter of water. Before introducing the P^{32} the excess debris was removed from the trays.

The larvae were now left undisturbed for the remainder of their development cycle except for the addition of 40 gms. of ground laboratory chow per tray, on August 19, 20(twice) and 21. A partial feeding also was made on August 22.

Observation of the trays indicated virtually no mortality among the crowded larvae or pupae.[2]

In each tray, sample volumes were taken, the estimated number of larvae in each sample being related to the number of larvae actually counted in several similar volumes. Computed on this basis, approximately 2.1 million larvae were collected and tagged. From examination of larvae it was found that 92 percent of the specimens were *A. taeniorhynchus* and 8 percent *A. sollicitans*.[3] The preponderance of the former species, while expected, was far greater than anticipated.

As a check on the radioactive qualities of the adults, several samples of larvae and pupae were removed from the trays and allowed to emerge in a laboratory cage. Monitoring these specimens with a laboratory count rate meter showed the males of *A. taeniorhynchus* to have counts per mosquito from 1,500 to 4,500 CPM, whereas in the females the radioactivity ranged from 6,000 to 12,500 CPM. A single female *A. sollicitans* had a count of 11,000 CPM.

Emergence of adult mosquitoes began approximately 7 days after the eggs were flooded, the bulk of the specimens issuing forth during August 22 and August 23. By nightfall on August 23 adult mosquitoes covered the inside of the tent and the surrounding vegetation. Departure of the adults began at 7:05 p.m. and by 7:30 p.m. few mosquitoes could be observed either in the tent or on the vegetation. On August 24 a minor second flight occurred and except for a few stragglers this ended the exodus of adults from the release point. As a means of distinguishing the adults leaving on August 24 from those of the previous night, a dye (Calco Oil Red) was dusted over the mosquitoes resting in the tent or on the vegetation on that date.

B. Appraisal

The principal method of evaluating the study was by means of standard and modified New Jersey Light traps. The original design for the distribution of the traps used the release point as the center, with traps at the circumference of concentric circles 2 miles apart for a distance of 20 miles from the release point. Potential trap sites were designated at approximately 2 mile intervals on each distance band (figure 1), a total of 331 potential sites within the entire study zone. Since it was impossible to activate all these sites because of the absence of electricity and unsuitable terrain in many locations, the design was reduced and modified in scope. To provide one area where the number of traps

[2] Two weeks after the release, examination of the water in the trays revealed a dense population of marine crustaceans and a few minnows suggesting that no serious depletion of the oxygen supply had occurred in the trays.

[3] This low percentage of *Aedes sollicitans* appeared questionable in view of the 14 percent present in the sod samples together with the supplementary eggs from the caged *A. sollicitans*. The most plausible explanation for this apparent discrepancy is that natural oviposition of *Aedes taeniorhynchus* in the study area caused the overwhelming predominance of that species.

in relation to the area involved would be equal at the various radii, all potential sites within one sector (90°) southwest of the release point up to the 10-mile distance were activated.[4] This sector lay on the mainland and included the metropolitan area of greater Savannah. The remainder of the traps were located in accordance with terrain and electric power as indicated in Figure 1.[5] With few exceptions each trap was located within 0.25 mile of its theoretical center. Each site was centered in an area of slightly more than 4 square miles except at the release point where the area covered only 3.1 square miles.

In addition to the traps within the study zone, one trap was operated on a ship[6] anchored 10 miles offshore from Savannah Beach or 21 miles E.S.E. of the release point.

Of the 93 traps used, 88 were serviced on a daily basis. Four stations, 60, 74, 75, and 81, located on islands, were visited on alternate days, each collection representing 2 nights of trap operation. One generator-powered unit (D) also was checked on alternate nights but each collection was the result of a single night's operation. Trap operation commenced 1 day prior to the release of the marked mosquitoes and continued for 23 days.

An attempt also was made to determine the levels at which the mosquitoes dispersed during the first night by airplane flights over the release point at altitudes of 30, 50, 70, 90, and 110 feet. However, all samples collected were negative for mosquitoes. Whether these results were the possible effect of wind upon the altitude reached by the migrating mosquitoes or whether the sampling technique was at fault was not apparent.

All mosquitoes collected were processed daily by a laboratory count rate meter,[7] the tagged specimens being sexed and identified. The unmarked mosquitoes were stored and their identities determined after field operations ceased.

During the nights of August 23 and 24, wind direction and velocity were recorded on an hourly basis at the laboratory, 0.25 mile from the release point. Subsequent wind readings were furnished by the U. S. Weather Bureau at Travis Field, 12 miles inland from the release point.

RESULTS. During the 23 days the 93 traps were operated, a total of nearly 77,000 mosquitoes was captured. Of these, 69 percent were *A. taeniorhynchus,* 14 percent *A. sollicitans,* with the remaining 17 percent being composed of other species, principally *Aedes vexans* Meigen, *Culex* spp., and *Anopheles* spp. Of the 53,000 *A. taeniorhynchus* captured, 11,500 were males while of the 10,700 *A. sollicitans,* only 370 were males. The relatively small number of mosquitoes collected was a reflection of the abnormally low mosquito densities present in the Savannah, Georgia, area in 1954. Since the summer broods of salt-marsh mosquitoes in this area are primarily a result of rainfall, the scarcity of rain in 1954 severely curtailed mosquito production. At the time of the release, there was little annoyance from salt-marsh mosquitoes, but 2 weeks later numerous adults were on the wing. This appearance of a new brood was noticeable in light trap densities where the average collection of *A. taeniorhynchus* increased from 5 specimens per collection to 52 specimens per collection.

Marked mosquitoes were recovered from 39 of the 93 stations. Despite the release of an estimated 168,000 *A. sollicitans,* only 8 tagged specimens of this species (4 males, 4 females) were captured and these or-

[4] One trap station on the 10-mile band did not operate because of the repeated failure of the portable power unit.

[5] Since much of the area north, east, and southeast of the release point was either water or marsh, ten traps placed therein were powered from portable gasoline generators. In figure 1 these are marked by letter rather than by number.

[6] The Savannah Lightship #518, United States Coast Guard.

[7] Model 1615B Nuclear Instruments Chemical Corp., Chicago, Ill.

curred in collections at the trap near the release site. As a result, in all subsequent discussion, the findings relate only to *A. taeniorhynchus*. A total of 428 specimens of this species were retrieved, of which approximately 13 percent were males.

Only 3 dyed radioactive *A. taeniorhynchus* were recovered, 1 male and 1 female at the release site and 1 female in trap 23.

From August 23 to September 10 the prevailing wind direction and velocity from 6:00 p.m. to 6:00 a.m. daily were as follows: August 24–August 31, 9 MPH, NE; September 1–5, 6 MPH, S; and September 6–10, 8 MPH, N. Except for variability in wind direction on August 28, the direction of the prevailing winds remained markedly uniform throughout

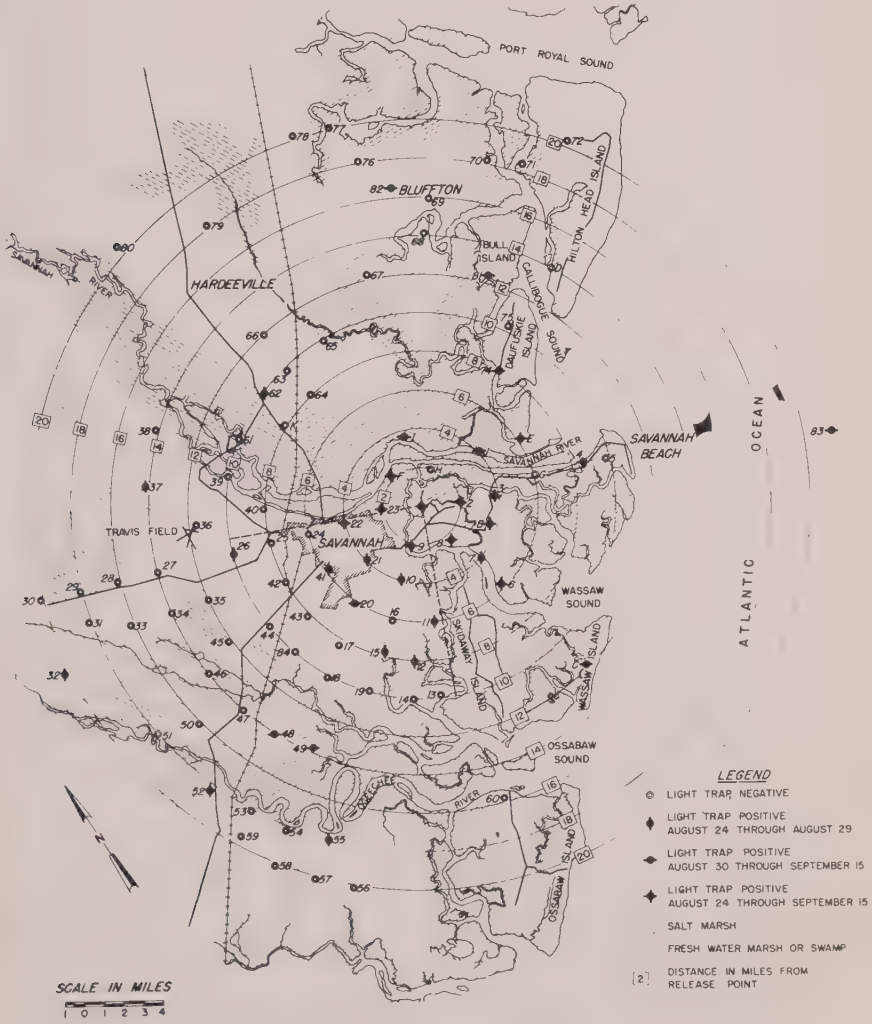

FIG. 1.—Study area, *Aedes taeniorhynchus* release, Savannah, Georgia (1954).

TABLE 1.—Distance, direction, and numbers of female *Aedes taeniorhynchus* caught by light traps after release on August 23, 1954. × indicates trap did not operate.

Trap No.	Distance in miles	Direction	August								September														Total
			24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	0.1	....	4	7	27	10	34	21	46		16*	12	4	3	6	3	2	4	2	..	1	..	..	..	2	204
2	2	E.SE.	×	..	4	×	..	2	..	1	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	9
8	2	S.	1	10	6	8	7	..	..	10	1	..	..	..	..	1	..	..	..	..	2	..	..	..	1	47
9	2	SW.	×	3	1	×	3	1	5	..	..	..	1	..	..	..	..	..	..	..	..	..	×	×	×	14
23	2	W.NW.	×	3	7	1	..	..	1	1	..	2	..	..	2	..	..	..	..	..	..	..	..	..	..	17
F	2	N.NW.	×	4	2	..	2	..	..	..	..	2	1	..	..	..	2	..	×	×	×	×	×	×	×	13
I	4	N.NE.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	×	..	×	×	×	1
J	4	E.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	×	×	×	1
3	4	E.SE.	..	..	4	2	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	8
B	4	S.E.	..	..	1	2	1	..	..	..	1	..	..	..	..	×	..	..	..	..	..	×	..	×	×	5
7	4	S.SE.	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	1
10	4	SW.	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	2
21	4	W.	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	×	..	1
22	4	W.NW.	..	2	..	1	2	..	..	1	..	..	1	..	..	1	..	..	..	..	..	..	..	×	..	8
E	6	E.	×	..	..	..	2	×	..	2	2	×	×	×	..	×	×	..	×	..	×	×	×	×	×	6
6	6	S.SE.	×	..	..	1	3	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	6
11	6	S.SW.	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
20	6	W.SW.	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
41	6	W.	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2

74	8	E.NE.	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	×	×	×	2
4	8	E.SE.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1
12	8	S.SW.	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
15	8	SW.	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
26	10	W.NW.	..	..	1	..	..	..	×	..	..	..	..	×	..	..	..	..	..	..	×	..	..	..	..	..	1
62	10	N.NW.	..	..	..	1	..	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	1
81	12	NE.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1
C	12	S.SE.	..	..	..	..	..	..	1	..	1	..	1	×	..	..	..	×	..	..	..	..	..	..	..	..	3
49	14	SW.	..	..	..	..	..	..	..	×	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
48	14	W.SW	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1
37	14	NW.	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
82	16	N.NE	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
55	18	SW.	..	..	..	..	..	1	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	1
52	18	W.SW.	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
32	20	W.	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
83	21	E.SE.	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Total, exclusive of Trap No. 1			1	26	30	20	20	7	9	16	10	5	5	1	2	5	3	1	1	..	2	..	..	..	1	165
Total			5	33	57	30	54	28	71		26	17	9	4	8	8	5	5	3	..	3	..	..	..	3	369

* Specimens released on August 24.

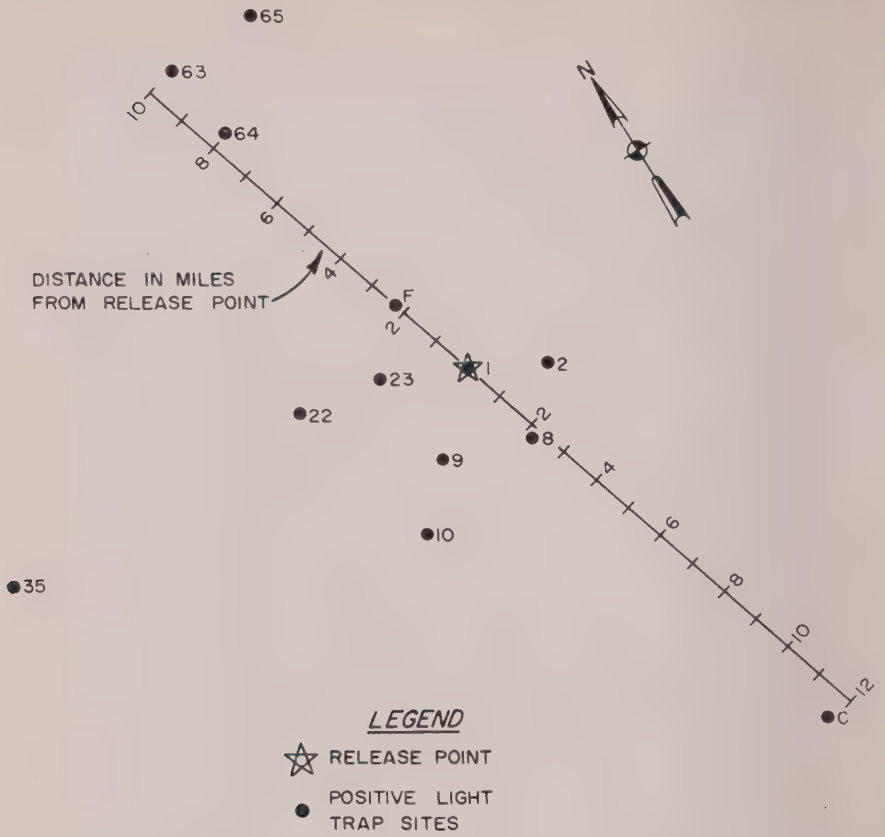

FIG. 2.—Recovery pattern of radioactive *Aedes taeniorhynchus* males.

each nightly period. As all weather data were recorded at one site, it was not possible to draw any definite conclusions as to the wind directions or velocities at other points over the test area.

Recovery of Female *A. taeniorhynchus*

The recoveries of tagged adult female *A. taeniorhynchus* in relation to distance, direction and numbers are given in Table 1. In the collections made the night of the release, only 1 marked mosquito was collected outside of the release point trap, the site of this collection being 2 miles away. On the second day, 26 adults were taken at distances up to 8 miles, on the third day 30 adults up to 14 miles, and on the fourth day 20 adults up to 20 miles. All of these maximum distances were northwest to southwest of the release point.

During the first six trapping days the majority of the positive sites beyond the 4 mile zone were located in the southwest to northwest areas.

In subsequent recoveries (August 30–September 4) a shift appeared in the distribution of positive stations, six of the nine positive sites being located in the north to southeast zones. This change was noteworthy inasmuch as these zones contained only 26 percent of the total number of traps distributed beyond 4 miles.

The majority of the tagged specimens (84 percent) was captured within 9 days after the release. During the last 9 days of the trapping period only 8 marked specimens were taken, the last specimen being recovered on the twenty-third day in a trap 2 miles from the release point.

In the 90° sector, which contained traps in proportion to area involved up to the 10-mile zone, the recovery of marked specimens decreased inversely with the distance from the release point (Table 2). Of the

TABLE 2.—Percentage recovery of 256 female *A. taeniorhynchus* in 90° sector at different distance intervals

Distance (miles)	No. of Traps	Percent
0	1	79.7
2	2	12.1
4	3	4.3
6	5	2.0
8	6	1.6
10	7	0.6

103 specimens captured, more than 90 percent were collected within 4 miles. When the data for all sites were adjusted in relation to the number of sites per distance band, similar, although less definite, relationships were apparent.

The single trap operated within 200 yards of the release site captured more radioactive mosquitoes than all other stations combined. As with the remaining stations, the first 9 days' collections yielded most of the marked specimens (81 percent).

Recovery of Male *A. taeniorhynchus*

The recapture of marked male *A. taeniorhynchus* (Table 3, figure 2) was less fruitful than that of the females, only 13 specimens (23 percent) being taken in stations outside of the release point. During the first night of trapping, 1 male was captured 4 miles southwest of the release site. Within the next 4 days, 3 other trap sites within 4 miles yielded 3 tagged specimens. On the fifth night 1 adult was captured 10 miles northwest from the release point. The maximum dispersion recorded for male *A. taeniorhynchus* was 12 miles, 1 specimen each being collected at 2 stations west and southeast of the liberation site. The last male mosquitoes recovered in these stations were taken 2 weeks after the main flight.

At the release point station male specimens were collected for the first eight nights of trapping. Two males were taken on the night prior to the main exodus of mosquitoes from the breeding site, thus indicating that some movement of the marked specimens occurred on August 22. Intermittent recoveries of tagged males at this site continued for almost 3 weeks.

DISCUSSION. The interpretation of the findings from a single dispersion study must be considered in the light that the data relate only to the area involved and to the ecologic conditions which prevailed during the period of the study. In addition, recognition must be given to the limitations of the sampling devices and their pattern of distribution.

As the data (Figure 1) show, marked female *A. taeniorhynchus* were captured at all stations within 4 miles of the release point during the period of August 24 through 29 except at sites H, I, and J. Although the prevailing winds for that period favored dispersal to the south and west, the recoveries in certain traps (F, 2, 3) indicated movement upwind. On an overall basis the vast majority of tagged female mosquitoes was taken south and west of the release point but since trap distribution favored these sectors, definite conclusions cannot be made as to the importance of wind movement.

Provost (1952) postulated that the initial flight of *A. taeniorhynchus* is nonappetential in nature, the mosquito flying not in response to food, mating, or oviposition stimuli, but more from an "urge to flight." Provost also suggested that meteorological and topographical conditions exert a major effect upon the pattern of the initial migration. In contrast to the 44 percent of the tagged female *A. taeniorhynchus* recovered at 6 to 10 miles in the Florida study

TABLE 3.—Distance direction, and numbers of male *Aedes taeniorhynchus* caught by light traps after release on August 23, 1954. × indicates trap did not operate.

Trap No.	Distance in miles	Direction	August								September												Total
			24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	
1	0.1	....	3	4	1	5	4	2	14*		..	..	..	..	..	..	2	1	..	..	7	1	44**
2	2	E.SE.	×	..	..	×	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1
8	2	S.	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
9	2	SW.	×	..	..	×	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
23	2	W.NW.	×	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
F	2	N.NW.	×	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
10	4	S.W.	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2
22	4	W.NW.	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
64	8	N.NW.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	×	..	..	..	..	..	1
65	10	N.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1
63	10	N.NW.	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
C	12	S.SE.	..	..	..	..	..	..	..	..	..	..	..	×	1	..	..	×	..	..	..	..	1
35	12	W.	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Total, exclusive of trap No. 1			1	..	..	1	3	..	1	3	1	..	..	1	1	1	..	..	..	..	..	..	13
Total			4	4	1	6	7	2	18		1	..	..	1	1	1	2	1	..	..	7	1	57

* Includes specimen released Aug. 24, 1954.
** Does not include 2 ♂ captured August 23.

(Provost, 1952) only 16 percent were taken at that distance interval in the Savannah, Georgia, release. Besides a low percentage recovery of marked mosquitoes at these distances, only 33 percent of trap sites therein recovered marked mosquitoes whereas in the Florida release 90 percent of the trap sites at 6 to 10 miles yielded radioactive *A. taeniorhynchus*. These differences in the two dispersion patterns apparently were due to variations in the environmental or biological factors which prevailed at the two test localities.

The movement of the marked brood was random, with reduced recoveries at greater distances, the distance traveled apparently being a function of time. In postrelease days 1 and 2 in the 90° sector, all of the sites at the 2- and 4-mile bands were positive whereas only 1 station beyond that distance collected marked mosquitoes. During the next 2 days, 4 stations at the 6-, 8- and 10-mile bands became positive for tagged specimens. Quantitatively, the data showed that the bulk of the brood remained close to the release point. Of the 369 marked females recovered, 204 came from the trap 0.1 mile from the release point, 100 from the 5 traps on the 2-mile band, 27 from 8 traps on the 4-mile band, 17 from 5 traps on the 6-mile band, and 21 from the remaining 16 traps in the 8- to 20-mile range.

Recoveries of tagged females were highest during the second through the fifth night of trapping at the sites 2 or more miles from the release point. The single trap at 0.1 mile yielded peak catches of 27 and 34 females on the third and fifth night. These findings suggest that the adult female mosquitoes are not repelled by light to the extent stated by Nielsen and Nielsen (1953) who indicated that females were not attracted to light until in a condition to oviposit (approximately 7 days). Provost (1952) indicated that the adult females showed their initial light attraction in approximately 5 days. In this study the adult females of 3 days age responded to light attraction as indicated by the recovery rates on August 25 (Table 1).

Nielsen and Nielsen (1953) reported a 5-day cyclic behavior pattern of the adult female which Provost (1952) fitted to his dispersion data in relation to a 5-day cycle of light attraction periods. If the data (Table 1) exclusive of trap 1 are considered, peak recoveries occurred on the third and eighth days.[8] While the inception of the peaks occurred two days earlier than those of Provost (1952) the trends shown for the positive recoveries in the two experiments are similar. The data support a cyclic pattern of adult activity but the variation in the onset of the initial light attraction period indicates that further studies are required on this phase.

Prior to the departure of the tagged population at dusk on August 23, the marked females attacked the observer readily. Since all specimens were 12 to 36 hours old, their tendency to bite was somewhat contrary to the findings of Nielsen and Nielsen (1953), whose data indicated biting to occur when the females were 4 days of age. However, no quantitative data are available to indicate what proportion of the population was involved in this biting activity.

The capabilities of the females to migrate considerable distances within short periods is shown by the recovery of specimens at 10 to 20 miles within 4 days after their release. While these findings give no information on the length of a single night's movement, the capture of 1 tagged mosquito on the light ship 21 miles from the release site and 10 miles from the nearest land indicates that this species has the potential to move extensive distances in continuous flight.

The rate of recovery of tagged males resembled that of the females, the majority of the specimens being taken in the trap 0.1 mile from the release point. Five

[8] Data for trap 1 reflect peak catches on the 3rd and 5th days but since small numbers of mosquitoes emerged from the breeding trays for several days after August 23 these peaks may have been influenced by such emergence.

marked male mosquitoes were found at 2 miles, 3 at 4 miles, 1 at 8 miles, 2 at 10 miles and 2 at 12 miles. In both time and distance traveled, the data differed from those of Provost (1952). His findings showed all male recoveries within 2.1 miles and within 3 days after release of the marked population. At trap 1 (0.1 mile) marked males were taken for 20 days after the release. At distances of 8, 10, and 12 miles single specimens entered traps 12 to 13 days after liberation. While greater numbers of tagged male mosquitoes were recovered near the release point, the numbers taken at 2 to 12 miles distance suggest that males can perform migration comparable to that of the female.

The assumption that capture at a certain point indicates sustained flight from the release site is not valid except in the case of sites that were positive the first night of trapping. All of the later recoveries of marked females could well have been the result of secondary, tertiary, or later migrations. Thus when all recovery points are established qualitatively, it is apparent that the original population, while initially displaying a somewhat directional movement, eventually distributed itself in a random pattern. The number of flights involved in this ultimate dispersion is debatable.

SUMMARY. 1. From a release of approximately two million radioactive *Aedes taeniorhynchus* near Savannah, Georgia, 428 marked specimens, of which 13 percent were males, were recovered. Recapture of tagged females was made at the maximum distances of trap locations (18 to 21 miles). However, most of the radioactive females (90 percent) were collected within 4 miles of the release point, the number of recoveries decreasing as the distance increased. Females were observed to bite readily prior to their departure from the release site.

2. Radioactive male *A. taeniorhynchus* were recovered at maximum distances of 12 miles and for periods of 12 to 20 days after release. The majority of the male recaptures occurred near the release point, but recoveries were made at 2, 4, 8, 10, and 12 miles.

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The AMCA meetings on February 23–26, 1958 in Washington, D. C., should be a good time to visit the many sites of historic, cultural and scientific significance that you have always wanted to see: the National Museum, the Smithsonian Institution, the Corcoran Gallery, the Mellon Gallery, the Shakespeare Library, the Army Medical Museum, Washington, Lincoln and Jefferson memorials, and many others too numerous to mention.

TOXICITY OF THREE PHOSPHORUS INSECTICIDES TO COLD WATER GAME FISH

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Recent experimental work by Gahan and Mulhern (1955) and by Gahan and Noe (1955) on the control of mosquito larvae in irrigated pastures or rice fields has demonstrated considerable promise for solubilized toxicants introduced by the drip method (Gahan *et al.*, 1955). Tests of this technique with three phosphorus insecticides were planned for pastures at Fort Klamath in central Oregon for June 1956. However, as the tail waters of irrigation are returned to the streams and the canals themselves often contain substantial populations of trout, it was deemed advisable to do preliminary toxicity tests with fish. For this purpose the Oregon Game Commission Trout Hatchery at Klamath Agency, Oregon, provided all facilities and fish.

Hatchery troughs 31 feet long, 14½ inches wide, and 7¾ inches deep were provided for the tests. Spring water at 46° F. entered the troughs from a pipe so as to cause a turbulence assuring thorough mixing, and midway of the trough a spillway dropped the water about 8 inches to remix and aerate the flow. Flow was regulated to a constant 10 g.p.m.

Continuous application of the insecticides was accomplished with the automatic drip dispenser. Parathion was introduced as a solubilized formulation containing 20 percent of technical parathion and 80 percent of Triton X-100. Dipterex and Phosdrin were introduced as aqueous solutions.

Five fingerlings and three 8- to 10-inch legal-size Rainbow and/or Eastern Brook trout were used in each experiment. The trout were confined in wire fry baskets approximately 25 feet from the point of introduction of the insecticide.

PARATHION caused no mortality of fish when dispensed at rates of 0.05, 0.1, 0.5, and 1.0 p.p.m. over periods of 14, 14, 28, and 28 hours, respectively. Excessive foaming of the formulation made higher concentrations impossible, but these results indicate that mortality of trout is unlikely at the low concentrations (0.01 p.p.m.) needed to kill mosquito larvae.

DIPTEREX also appeared not to affect fish held in water treated with 1 and 10 p.p.m. for 72 and 24 hours. In all cases the fish were held for at least 48 hours after the toxicant was discontinued, for observation of possible delayed effects. Dipterex is effective against mosquito larvae at 0.2 p.p.m.

PHOSDRIN was indicated to be highly toxic to trout in these tests. Complete kill of fish resulted at rates of 0.05, 0.1, 0.5, 1.0 and 10 p.p.m. introduced over periods of 72 and 4 hours, 80, 30, and 15 minutes, respectively. Fish exposed for 180 hours at 0.01 p.p.m. showed symptoms of poisoning but were not killed. One of 10 Eastern Brook fingerlings exposed to 0.025 p.p.m. for 156 hours died.

Poisoning could be arrested by removing the fish to uncontaminated water. Fish so handled appeared to recover completely within a few hours. Age or species did not exhibit any marked influence on the susceptibility to the insecticide. Mosquito larvae confined to the treated troughs were not killed at rates of 1 p.p.m. or less, and thus were less susceptible than the fish.

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EFFECTS OF VARIOUS POISONS ON *ANOPHELES* HEART RATES

JACK COLVARD JONES

U. S. Department of Health, Education, and Welfare, Public Health Service, National Institutes of Health, National Institute of Allergy and Infectious Diseases, Laboratory of Tropical Diseases, Bethesda, Maryland

This note summarizes the general effects of a wide variety of poisonous compounds (mostly insecticides) on the heart rates of intact, freshly fasting *Anopheles* mosquito larvae (*A. quadrimaculatus* Say; LTD strain; Diptera, Culicidae).

Most of the studies were made with unsexed fourth instars of variable ages (2 to 36 hours in the stadium). Heart rates were calculated from continuous recordings from 5 to 20 individuals as previously described (Jones, 1956a). Observation times varied from approximately 20 minutes to not more than 2 hours per larva.

When intact freshly fasting larvae were placed in either p,p'-DDT (10^{-4}, 10^{-5}), methoxychlor (10^{-4}), dieldrin (10^{-4}, 2×10^{-5}), toxaphene (10^{-4}), parathion (10^{-4}), ethyl p-nitrophenyl thionobenzene phosphonate (EPN; 10^{-6}), sodium pentachlorophenate (PCP; 10^{-2} to 10^{-4} molar), or 2,4-dinitrophenol (DNP; 10^{-4} to 10^{-5} molar), the heart rates did *not* decline as did those of controls fasting in distilled water or in 1 percent acetone, but remained approximately constant, essentially like the rates of *normal* larvae feeding in culture water or in distilled water containing fresh food (as in fig. 1, line B). Male and female larvae [1] did not differ in their cardiac responses to either DDT or dieldrin prior to convulsions.

Immersion of larvae in either eserine (10^{-5}, 30 minutes), neutralized atropine (10^{-3}, 30 minutes), or freshly half-saturated ether solution (in a closed dish for 5 to 10 minutes) did not alter the basic cardiac reaction when larvae were then placed in DDT.

[1] Larvae were sexed by examination of the antennal discs as described by Jones ('57).

Cardiac stimulation greatly exceeding a normal feeding rate was found with very high concentrations of DNP (10^{-2} and 5×10^{-3} molar). The acceleration was progressive and occurred without the larvae's becoming hyperactive.

Heart rates of larvae in sodium fluoride (10^{-2}) were normal compared to sodium chloride controls (0.24 molar) for 55 minutes, whereupon they rapidly diminished and the hearts dilated abnormally and stopped beating in 60 to 70 minutes (as in figure 1, line D). In sodium met-

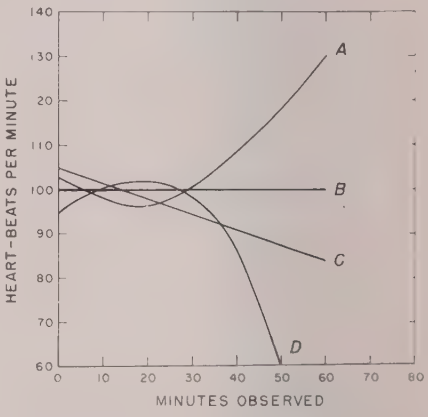

FIG. 1.—Diagram of principal cardiac responses of intact *Anopheles* larvae under normal and abnormal situations.

Line A.—Marked progressive cardiac stimulation. Type of reaction seen with strong DNP.

Line B.—Mild stimulation as found in normal feeding larvae and as occurs during poisoning with DDT, dieldrin, BHC, toxaphene, EPN, weak DNP.

Line C.—Normal cardiac decline. Type seen in larvae fasting in distilled water, 1 percent acetone, phenothiazine, rotenone, pyrethrins.

Line D.—Cardiac depression. Type seen with sodium fluoride. Similar but more rapid with sodium metarsenite.

arsenite (10^{-2}) the rates were like those of saline controls (0.08 molar) for only 15 minutes, then the heart either beat very slowly or beat normally but with very long stops in systole between every three or four normal contractions before final arrest.

Prior to the moribund stage, relatively slight decreases in the heart rate were found with highly concentrated p-chloromercuribenzoate (a powerful sulfhydryl inhibitor; 2×10^{-4} molar), rotenone (about 10^{-4}), phenothiazine (10^{-4}), or pyrethrins (I and II; 10^{-6}).

Mild cardiac stimulation of fasting rates in *Anopheles* larvae has already been reported with such varied treatments as certain concentrations of carbon dioxide and oxygen (Jones, 1956b), sodium, potassium, and calcium chlorides (Jones, 1956c), and a few drugs (*viz.*, eserine and nicotine) (Jones, 1956d). High concentrations of potassium have been reported to give marked cardiac stimulation of approximately the same magnitude as DNP (Jones, 1956c).

The relative indifference of the mosquito heart to many poisons is not peculiar, for this organ is said to be without nerves and is refractive to drugs known markedly to affect cardiac nerves of other insects (Jones, 1954, 1956d). The mosquito heart reacts to many poisons essentially like the cockroach heart (see Krijgsman *et al.*, 1950, Orser and Brown, 1951, Naidu, 1955). This seems surprising since the cockroach has a well-innervated heart (Alexandrowicz, 1926, McIndoo, 1945) which reacts to many drugs in a manner quite unlike that of the mosquito larva (Krijgsman and Krijgsman-Berger, 1951, Naidu, 1955, Jones, 1956d). It is worth noting that the reactions of *Anopheles* and cockroach hearts to DDT (decrease in the roach, mild[2] stimulation in *Anopheles*) are very different from the reactions of the hearts of acutely poisoned dogs and monkeys, for in these mammals DDT is said to sensitize the myocardium to extrinsic epinephrine and intrinsic sympathin and to lead to the onset of ventricular fibrillation (Phillips *et al.*, 1946).

In summary, it has been found that the myogenic heart of the *Anopheles* mosquito larva is only mildly affected by a number of poisonous compounds. Only one toxicant, DNP, led to a truly marked stimulation of the heart rate and produced this effect only in massive doses.

[2] Yamasaki and Ishii (1950) found the heart of *Locusta* was definitely depressed after perfusion with DDT.

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OPERATIONAL AND SCIENTIFIC NOTES

RESISTANCE OF THE PUERTO RICAN FILARIASIS VECTOR, *Culex quinquefasciatus*, TO DIELDRIN. The ineffectiveness of DDT in controlling *Culex quinquefasciatus* larvae in San Juan, Puerto Rico has been recognized since 1952. Recent observations indicated that the same species was also resistant to dieldrin and the tests reported here were performed to obtain objective information.

The techniques recommended by the U. S. Department of Agriculture * were used for testing susceptibility of fourth instar larvae from representative habitats. The method cited compares the 24-hour mortality of the allegedly resistant strain of *C. quinquefasciatus* with that recorded for a known non-resistant strain at insecticide dosages of 0.1, 0.025, 0.05, 0.012, and 0.005 p.p.m. The mortalities at the 0.025 p.p.m. dosage level are indicative of the general results obtained. Table 1 shows the susceptibility of larvae to concentrations of 0.025 p.p.m. of DDT, dieldrin, EPN, lindane, and chlorthion.

It is evident that, while Chlorthion and EPN caused a high percent mortality (over 80 percent in most tests), the mortality resulting from exposure to DDT and dieldrin was markedly lower than expected.

These data seem to indicate partial and low resistance to DDT and definite uniform high resistance to dieldrin, and suggest the need for continued periodic inquiry into this phenomenon. —Alfredo Casta Velez, Biologist, Bureau of Vector Control, Commonwealth of Puerto Rico, Department of Health, San Juan; and Frederick F. Ferguson, Biologist, Puerto Rico Field Station, Communicable Disease Center, U. S. Public Health Service, San Juan. Contribution of the U. S. Department of Health, Education and Welfare, PHS, CDC, Atlanta, Ga., and the Department of Health, Commonwealth of Puerto Rico, San Juan.

TABLE 1.—Tests on the resistance of Puerto Rican *Culex quinquefasciatus* fourth-instar larvae to insecticidal action based on 24-hour mortalities at 0.025 p.p.m.

Insecticides	Total Stations	Dead	Alive	24-Hour Mortality	Total Replicates
DDT	8	78	647	10.76%	29
Dieldrin	7	2	473	0.42%	19
EPN	4	286	64	81.71%	14
Lindane	1	24	51	32.00%	3
Malathion	1	9	66	12.00%	3
Chlorthion	2	186	14	93.00%	8

* "A Laboratory Method for Determining Insecticide Resistance in Mosquito Larvae"—published by U. S. Department of Agriculture, Agricultural Research Service, Entomology Research Branch, and reproduced by U. S. Naval Air Station, U. S. Navy, Preventive Medicine Unit No. 1, Jacksonville, Florida (PMU–1 Tech. Bull. 55–1).

Two mosquitoes once lit on the features
Of two fair and peroxided creatures.
When asked by what right
They replied, "We're not tight . . .
We're just seeing the game from the bleachers."

EDITORIAL

A YOUNG ADULT AND A TEENAGER

DONALD R. JOHNSON
Chairman Membership Committee

During the 22 years since the American Mosquito Control Association was founded, this Association has grown steadily to adulthood. No longer is MOSQUITO NEWS an infant either. It is a teenager, having been in existence for 16 years. This pair, one a vigorous young adult and the other a progressive teenager, have bonded mosquito workers together around the world. They represent the common interests of a multiude of persons all engaged in the study and control of mosquitoes.

At the present time our Association has a combined membership and subscription list of approximately 1,300. MOSQUITO NEWS is therefore sent to 1,300 individuals or institutions both in the United States and elsewhere in the world. It is highly respected and recognized by everyone with an interest in mosquitoes. Unfortunately, many persons who *should* belong to AMCA are not yet members. If *every* member takes it upon himself to talk or write to someone who is not a member, our membership should increase by leaps and bounds. This will not only strengthen AMCA but will permit the expansion and continued improvement of MOSQUITO NEWS.

Enclosed with this issue of MOSQUITO NEWS is a membership application form. Every member should attempt to obtain a new member, thereby permitting our young adult to grow in size and stature; our teenager at the same time will become even better known and more vocal as adulthood is approached. Let's all pitch in and help. Additional copies of the membership application are available from the Executive Secretary, Box 278, Selma, California.

GET A NEW MEMBER FOR AMCA NOW!

MOSQUITO CULTURE TECHNIQUES AND EXPERIMENTAL PROCEDURES

By HELEN LOUISE TREMBLEY DURKEE

(A.M.C.A. Bulletin No. 3)

This is the only complete up-to-date reference on mosquito culture. It contains information on Rearing, Development and Behavior, Disease Transmission, Precautions and an extensive bibliography.
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ASSOCIATION NEWS

FOURTEENTH ANNUAL MEETING
AMERICAN MOSQUITO CONTROL ASSOCIATION
February 23–26, 1958
WILLARD HOTEL, WASHINGTON, D. C.

THE SOUTHEAST CENTRAL REGION will serve as host for the 1958 meeting. Regional Director William E. Bickley, Department of Entomology, University of Maryland, College Park, Maryland, has been appointed General Chairman by President Arthur W. Lindquist.

Hotel reservations should be made directly in accordance with announcement mailed to all members.

Members are requested to indicate their preference for the bus tour (Bethesda or Beltsville) on February 25, by writing directly to Arthur S. Kidwell, Department of Entomology, University of Maryland, College Park, Maryland.

CALL FOR PAPERS

1. Submit a title of your paper, an abstract, and an indication of the type of projector needed to CDR John M.Hirst, Preventive Medicine Unit No. 6, Navy No. 128, FPO, San Francisco, California. *Deadline for receipt of this information—November 1, 1957.*

2. All paper reading sessions will be timed and carefully scheduled. The length of the program indicates the necessity of limiting the time of presentation of papers to a maximum of 10 minutes. Members are urged to rehearse in advance of the meeting to be sure that their paper can be presented within the allotted time in an interesting and comprehensible manner. Bear in mind also that for publication in MOSQUITO NEWS free of additional expense, the Editor must have a ribbon copy typed in accordance with the published regulations.

3. *To be included in the printed program, all titles must be accompanied by a typed, informal abstract of 150 words or less.* In preparing these abstracts, members should bear in mind that, in addition to acquainting other members with their data and general conclusions or results, abstracts will be made available to the press as a source of factual information. Therefore, as non-technical language as possible should be used.

REGIONS
OF THE
AMERICAN MOSQUITO
CONTROL ASSOCIATION

I CANADA
II NORTH ATLANTIC
III SOUTH ATLANTIC
IV NORTHEAST CENTRAL
V SOUTHEAST CENTRAL
VI NORTHWEST CENTRAL
VII SOUTHWEST CENTRAL
VIII NORTH PACIFIC
IX SOUTH PACIFIC
X MEXICO, CENTRAL, AND SOUTH AMERICA

NEWS AND NOTES

WE WORKED RIGHT UP TO PRESS TIME LAST ISSUE AND THE PRESS CAME DOWN AND BIT OFF A PIECE OF OUR HAND SO WE RUSH UP WITH SOME BELATED NEWS NOW ABOUT PRESIDENT ART LINDQUIST. He was invited to attend and participate in the World Health Organization work conference held at Geneva, Switzerland, during July 25 through 31. The main objective of the meeting was to consider ways in which the amount of research being performed on the insect resistance problem can be increased, and to suggest means for improving world-wide coordination of research on this important problem. As representative, not only of the United States Government but also of our American Mosquito Control Association, two organizations in which we all take a fairly strong interest, it is obvious that Art's comments will be eagerly awaited upon his return.

DR. LINDQUIST ALSO ATTENDED THE RECENT INTER-AMERICAN SYMPOSIUM ON THE PEACEFUL APPLICATIONS OF NUCLEAR ENERGY, which was held on May 13–16, at the Brookhaven National Laboratory on Long Island. He presented a paper reviewing recent work in the Entomology Research Division on the use of radioisotopes in studies on the biology and control of insects. The Conference was particularly intended for the benefit of the group of approximately 190 Latin-Americans in attendance, giving them information on nuclear physics, the management of atomic energy programs and the uses of radioisotopes in medicine, biology and agriculture. Talks were given by Dr. Milton S. Eisenhower, President of Johns Hopkins University, Lewis L. Strauss and Willard F. Libby of the U. S. Atomic Energy Commission. An interesting part of the program was a tour of the facilities of the laboratory, including the nuclear reactor, the Cosmotron and the huge new Synchrotron, the world's largest accelerator, which is now under construction.

ANOTHER ITEM FROM THE PRESIDENT'S DESK IS A LETTER FROM DR. I. R. MAXWELL OF THE PERGAMON INSTITUTE OF LONDON AND NEW YORK. This non-profit institute can make available English translations of results of research and development in various countries, including the U.S.S.R. They asked that the availability of this service be made public to the membership of the association. Also, if any of our members have a knowledge of Russian and are sufficiently qualified to take translations, they may become members of the Institute's panel of paid translators. It is the hope of the Institute that Societies such as ours will make use of the Institute's facilities and support its work in every way they can.

OUR MAIL HAS BEEN HEAVY THIS MONTH WITH NEWS OF CHANGES OF ASSIGNMENTS AND ADDRESSES. PRESIDENT-ELECT, COMMANDER, DOCTOR "Mo" (JOHN M.) HIRST leaves these shores on the 24th of August to sail for the paradise of the Pacific, where his new berth at Pearl Harbor awaits him. There he will be heading up Preventive Medicine Unit No. 6, whose address is Navy No. 128, FPO, San Francisco. Those in Mosquito Control activities in California especially bewail the separation and on 17 August tendered "Mo" and his family a farewell dinner where he was assured that nothing but holding the meetings next year in the soft surroundings of Hawaii (and at the reduced rates most of us would require to get there) will assuage their grief.

EXCHANGING WITH MO WILL BE DR. (AND ALSO COMMANDER) DICK HOLWAY, ALSO OF AMCA AND WIDELY KNOWN, who went to Hawaii after valiant service in Bureau of Medicine and Surgery, Washington, D. C., and will now be the Insect Vector Control Officer, Office of the Inspector, Naval Medical Facilities, Pacific Coast, at Mo's old address, Bldg. 83, Naval Air Station, Alameda, California. Dick's coming will be as welcome as Mo's leaving will be regretted. It's just a damn shame we can't eat our cake and have it too, ain't it?

AND SPEAKING OF MOVING, WHAT DID WE TELL YOU ABOUT UNCLE HARRY STAGE AND HIS GLOBE-TROTTING? This time it's only a *little* move . . . really just across the street for Harry. He's now with the Department of Health of Washington State, implementing their new enabling act so that the several counties of eastern Washington can get rid of their *Culex tarsalis* and accompanying encephalitis problem. "Have had 14 months vacation so thought I should settle down again," he notes, "We'll soon be writing mosquito control history in Washington State so brace yourselves." We're braced, Harry. Start the running commentary real soon now, hear? (Harry's new address is . . . and we hope this is still current when it gets into print . . . Box 624, Pasco, Washington.)

MILTON H. BUEHLER IS BEING WELCOMED ABOARD AS THE NEW SPECIAL ASSISTANT FOR PEST CONTROL TO THE DISTRICT PUBLIC WORKS OFFICER, THIRTEENTH NAVAL DISTRICT, with headquarters in Seattle, Washington. He became entomologist for the District on July 10th after having resigned his position as Director of Mosquito Control Section, City and County Health Department, Eugene, Oregon, as of 31 May. Milt's joining is good news to the mosquito killing fraternity of the Navy.

ART KIDWELL DOFFED HIS ARMY UNIFORM SOME MONTHS AGO and is now entomologist with

the University of Maryland's Mosquito Control Program, according to Dr. WILLIAM E. BICKLEY. Dr. JAMES R. FOSTER and Mr. STANLEY R. JOSEPH are assistant entomogolists in the same Program. On July 1, Dr. GEORGE S. LANGFORD became State Entomologist and Dr. Bickley, who has been acting in the capacity, became Head of the Department of Entomology of the University.

BILL BICKLEY ALSO SENT US A NOTE ABOUT DR. EUGENE J. GERBERG who has just returned from a trip to Guatemala, Costa Rica, Panama, Venezuela, Aruba and Trinidad. In Trinidad, he visited with Dr. H. P. S. GILLETTE, who is now Director of Medical Services of Trinidad, though he continues his interest in yellow fever and malaria control.

DR. FRED BISHOPP SENDS US A REPORT ON THE CELEBRATION OF THE HUNDREDTH ANNIVERSARY OF THE BIRTH OF DR. L. O. HOWARD, LONGTIME DEAN OF AMERICAN ENTOMOLOGISTS.

"The monumental work done by Dr. L. O. Howard on mosquitoes, flies and other disease-carrying insects as well as that done on various destructive and beneficial insects in general, was reviewed and praised at the celebration on June 11, 1957 of the 100th anniversary of his birth.

"This celebration was in the form of a banquet at the widely-known Cosmos Club in Washington, D. C. It was attended by 150 of his friends, and admirers of his great work. His daughters, Misses Lucy and Janet Howard and his grandson, Mr. Howard Payne, were honor guests. The banquet was under the auspices of the Entomological Society of Washington and the Insecticide Society of Washington. A joint committee made the arrangements, the committee consisting of W. G. Bruce, Paul Hubanks, Helen Sollers, J. S. Wade, and M. D. Leonard. The Presidents of the two Societies, Dr. F. L. Campbell and Dr. Elizabeth E. Haviland, spoke briefly and Dr. Mortimer D. Leonard, consultant to the Shell Chemical Corporation, was toastmaster.

"Interesting reminiscences of Dr. Howard were presented by Dr. Lyman J. Briggs, Director Emeritus of the National Bureau of Standards, Mr. John E. Graf, Assistant Secretary of the Smithsonian Institute, Dr. William M. Mann, formerly Director of the National Zoological Park, Dr. R. C. Roark, formerly Chief of the Division of Insecticide Investigations, U. S. Department of Agriculture, Dr. Thomas E. Snyder, leading expert on Termites, and Col. F. S. Haydon.

"Dr. Fred C. Bishopp, formerly Assistant Chief of the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture (and, of course, formerly President of the American Mosquito Control Association), gave an address reviewing the life and work of Dr. Howard, who served the U. S. Department of Agriculture for 53½ years, 33 of which were as Chief of the Bureau of Entomology. The outstanding role played by Dr. Howard in the development of a sound basis for looking toward control and even eradication of flies, mosquitoes and other disease carriers of world-wide importance was especially emphasized by Dr. Bishopp, as was also Dr. Howard's remarkable ability to interest and obtain active support from people around the world in making war on insect pests."

THE INTERNATIONAL COÖPERATION ADMINISTRATION SENDS US A RATHER LONGISH NOTE ABOUT DR. JOSEPH M. BUTLER who has been following in the footsteps of ERNESTINE THURMAN and her late husband in Thailand. In summary, Dr. Butler, who received degrees from the Universities of Kentucky and Utah, accepted appointment to Saudi Arabia in 1953 and went directly from there to Thailand in 1955, where he plans to continue after a period of stateside leave. He is stationed at Chiengmai, in the Northern Regional Office, some 400 miles north of Bangkok. In his work with the Malaria Control Training School, training in malaria control techniques has been given not only to all doctors and technicians from Thailand but also from other countries such as Laos, Indonesia and Nepal. This Thai-U. S. coöperative effort in malaria control is one in which both countries may take great pride. The remarkable achievements to date have already put Thailand well up in the forefront among the nations approaching completion of their campaigns to eradicate malaria.

DON GRANT'S SAN MATEO COUNTY (CALIFORNIA) MOSQUITO ABATEMENT DISTRICT, CHET ROBINSON AND MARV KRAMER'S ALAMEDA COUNTY MOSQUITO ABATEMENT DISTRICT, AND DICK PETER'S BUREAU OF VECTOR CONTROL were hosts recently to two alert mosquito control enthusiasts from Liberia. Messrs. Bleabay Bedell and James Nimley, presently studying in this country, and whose mosquito control careers commenced during the period when Dr. GEORGE BURTON was with ICA in Liberia, hope to be able to cram as much American know-how into themselves as is humanly possible during their stay, and they seemed well on the way to realizing their goal already.

THE VIRGINIA MOSQUITO CONTROL ASSOCIATION was able to make a very worthwhile contribution to its members recently when it sponsored an attractive eight-page booklet, nine by six inches, which tells the story of mosquitoes, and specifically Virginia mosquitoes, and of the control efforts exerted against them. Written entirely in non-technical language but in interesting, straightforward fashion, the booklet had a first printing of 26,000 copies and was distributed under their own names by the various mosquito control commissions.

THE VIRGINIA "SKEETER" ALSO TELLS HOW TWO OF THEIR MOSQUITO CONTROL COMMISSIONS HAVE BEEN REPAIRING LEAKY SPRAY CANS, using a simple, inexpensive, durable and highly ad-

hesive commercial plastic mending material. We'd be glad to give the name of his product if the company will buy an ad in Mosquito News, but pending the appearance of the ad, members wishing to know may write for a copy of the May and June SKEETER. The stuff is 80 percent steel and 20 percent plastic and is non-shrinking and non-expanding. It works like a good grade of putty and after hardening can be dressed with a file. Seven cans which would otherwise have been a total loss were reported to have been mended with this material with excellent results and at nominal cost.

MO HIRST IS RESPONSIBLE for the limerick on page 216. Any more limericks, anyone?

RECENTLY WE HAVE MENTIONED VARIOUS FAMOUS MEMBERS OF A.M.C.A. WHOSE WHO'S WHO'S (NO THAT IS NOT WHOAS) WE HAVEN'T RUN. There are so many famous persons in A.M.C.A. that we have a dickens of a time selecting whom to run, like the famous centipede that couldn't decide which leg came first. Well, we usually pick them by plunging our arm into the pile, and if you have any favorites we seem to have slighted, remember that we'll be until 1998 running everybody; so ask for the one you want.

ANYHOW, HERE'S CHARLIE WHITE OF NORTH CAROLINA. We've always considered that what the Governor of South Carolina said to the Governor of North Carolina was "What can we do to get us a man like Charlie White?" Well, North Carolina got him by his being born there, in Manson, on 27 September 1900 (Happy Birthday, Charlie!). He received his B.Eng degree from N. C. State and his Master of Public Health from the University of North Carolina. After finishing college he worked as resident engineer with the Tennessee State Highway Department until 1933, when he began to be introduced to malaria control by the North Carolina Department of Health and the U.S.P.H.S. He was State Director of Malaria Control in War Areas, during the war and of the CDC activities to 1950, and still holds a commission in the U.S.P.H.S. as a senior sanitary engineer. He is presently the Chief of the Insect and Rodent Control Section of the State Board of Health, of course, and also Chairman of the Salt Marsh Study Commission, as we indicated last issue. He is a member of a number of professional societies, is married, with a son in college, and says hunting, fishing, poker and gardening are his hobbies.

BILL FROHNE, who was recently noted as having moved from Alaska to the Philippines, was born in Nyack, N. Y., in 1908 and was married in 1935 (according to American Men of Science, which tells us more than most of our biographees ever do). He has three children and three degrees, his doctorate coming in 1937, from Michigan. He was with the U.S.P.H.S., beginning in 1936 at Savannah, Georgia, and was an associate entomologist and sanitarian-scientist with the U.S.P.H.S. Malaria Control in War Areas and Communicable Disease Center, after 1942. He was a member of the U.N. Relief and Rehabilitation Administration mission to Greece in 1945 and then went to the Arctic Health Research Center. In addition to his numerous papers on mosquitoes and malaria control, he has also written on desmids, asilids and other infrequently studied but important insects.

THE PERIPATETIC OTHER HALF of the California Bureau of Vector Control doesn't get around *quite* as much as its even more peripatetic chief but he's widely known in his own way so this can't be made into much of a guessing game. He was born in Bend, Oregon, in 1915, and went to San Jose State and Stanford, gaining his B.A. and M.A. from the latter institution, while simultaneously achieving the difficult feat of being a research assistant at said University and with Wallace and Tiernan. The Army had him from '42 to '45 and then he was a research associate for two years and then entomologist with the East Side Mosquito Abatement District (California) for two more. Since then he's been with the Bureau as Senior Vector Control Specialist, where he is noted (as are all in that organization, it seems) for his hard work. He says even his *hobby* is Natural History. WHO? Why JOHN R. WALKER. We already *told* you.

TRAVIS MCNEEL, one of the famous three authors of the famous reference bulletin on the mosquitoes of the Southeastern States, was born in Mississippi (we guess) and anyway went to school there, graduating from Mississippi State in 1923 to join the U. S. Department of Agriculture, Bureau of Entomology, in research on, of all things, cotton insects. Well, *that* didn't last long. In 1924, he was transferred to the Division of Insects Affecting Man and Animals and has been working ever since on mosquito ecology and control. He was stationed in Mound, Louisiana, for a number of years and later in Orlando, Florida. A few months before the war began he was transferred to the U.S.P.H.S. to work on salt marsh mosquito control; when the war started he was placed in Malaria Control in War Areas. After rendering great assistance to the military mosquito control effort (and we *do* mean great) he joined the CDC Malaria Eradication Program. In 1950 he was assigned to Little Rock, Arkansas, where he chairmanned the program on Insects of Public Health Importance in the eight Basin States. In 1954 he became Chief Malariologist to the United States Operations Mission to the Philippines where he stayed until this last year, when he went on to join the eradication program in Mexico, as we have recounted earlier.

REVIEWS AND ABSTRACTS

OBSERVATIONS ON THE OXYGEN CONSUMPTION OF SOME ADULT MOSQUITOES. By T. I. Mercado, H. L. Trembley,[1] and T. Von Brand, Physiol. Compar. Etoecologia 4(2):201–208. 1956. 9 refs. The rate of oxygen consumption of six species [2] of adult mosquitoes was studied. No definite signs were found that sex influences the rate of tissue respiration materially. Feeding with sucrose water or blood increased the rate of respiration rather considerably, but this increase was in most cases maintained for only a few days upon starvation. Sucrose-water fed specimens withstood starvation better than blood-fed ones.—Authors' summary.

THE DISTRIBUTION OF *Culex p. pipiens* AND *C. q. quinquefasciatus* IN NORTH AMERICA. By A. R. Barr. Amer. J. trop. Med. and Hyg. 6(1):153–165. 1957. 10 refs. The only reliable character for separating individual *pipiens* and *quinqefasciatus* was described by Sundararaman (1949). This is a ratio of two measurements of various parts of the male genitalia. . . . DV is the extension of the ventral arm laterally of the intersection with the dorsal arm. In specimens with a negative ratio the same measurement was used. Since there was no intersection of the arms, the point where they would have intersected had the ventral arm been longer was used. Both DV measurements were recorded and an average taken. D is the distance between the two intersections of the dorsal and ventral arms.—Excerpts from text.

The DV/D ratio was measured in about 3½ thousand males of *pipiens* and *quinquefasciatus*, mostly from North America. It was found that the average ratio in a collection of *pipiens* is 0.1 or less and in *quinqefasciatus* 0.6 or more. In individual specimens the ratio is usually less than 0.2 in the former and more than 0.4 in the latter. In North America north of 39° N. only *pipiens* is usually found; south of 36° N. only *quinquefasciatus* is generally present. Collections from between these latitudes may contain one or the other form, intermediates, or various mixtures of the three. There seems little doubt but that the forms do hybridize in nature. In some localities (Sacramento, Calif.) intermingling seems to be much freer than others (E. St. Louis, Ill.). At the present time it seems wisest to retain subspecific names for the two forms.—Author's summary.

THE MICROSCOPIC DIAGNOSIS OF HUMAN MALARIA. II. A MORPHOLOGICAL STUDY OF THE ERYTHROCYTIC PARASITES. By J. W. Field and P. G. Shute. Studies from Inst. for Med. Res., Fed. of Malaya. No. 24, 243 pp. 59 plates. This well-illustrated book on thin-film diagnosis is a companion volume to Study No. 23 which is an account of the morphology of the Malayan parasites as observed in thick blood films.

The present study describes and illustrates the appearance in thin blood films of plasmodia found in man *P. falciparum vivax, malariae,* and *ovale,* with particular emphasis on the forms prevalent in Malaya. The drawings of the Malayan parasites are original. Unlike Study No. 23, the present volume contains information on *P. ovale,* a species not known to occur in Malaya. There are also chapters on the history of microscopic diagnosis in human malaria, the parasite and the host red cell, methods of examination, and technical miscellanea.

In the Appendix is given something on the morphology of malaria parasites as damaged by quinine, mepacrine, chloroquine, amodiaquine, proguanil, pyrimethamine, and pamaquine. Malariologists around the world will find much in the book to stimulate their continued interest in this complicated and intriguing field of research. —Harry H. Stage.

FOREST MOSQUITOES ASSOCIATED WITH SYLVAN YELLOW FEVER IN NICARAGUA. By P. Galindo and H. Trapido. Amer. Jour. trop. Med. Hyg. 6(1):145–152. 1957. 11 refs. The results are given of forest canopy mosquito surveys at three places in Nicaragua where there was evidence of sylvan yellow fever activity during 1952 and 1953. At these localities five species of *Haemagogus* were taken: *spegazzinii falco, iridicolor, m. mesodentatus, equinus,* and *anastasionis,* the last named only on the Pacific slope, and the first three only on the Caribbean slope. *H. iridicolor* is also present on the Pacific slope in small numbers, but was not in the collections made at the two fixed stations operated there. Also present and of interest as possible vectors were *Aedes leucocelaenus clarki* and *Trichoprosopon magnus* on the Caribbean side only, and *Sabethes chloropterus* on both the Caribbean and Pacific versants. On epidemiological grounds *H. equinus* appears to have been the vector on the Pacific side and *H. iridicolor* the principal vector on the Caribbean slope. The possible role of *S. chloropterus,* considered an important species in carrying virus over the dry season in Panama, could not be assessed as the Nicaraguan collections were made only in the rainy season. Also in doubt is the possible part played by *Trichoprosopon magnus,* the commonest arboreal mosquito at the Caribbean side stations, since its ability to transmit has not yet been determined. It is thought that the numbers of three species known to be vectors elsewhere, *H. spegazzinii falco, H. m.*

[1] Now H. L. Durkee.

[2] *Aedes aegypti, A. atropalpus, Culex pipiens, Anopheles albimanus, A. quadrimaculatus, A. freeborni.*

mesodentatus, and *A. leucocelaenus clarki* were too small for them to have been significantly involved in transmission.—Authors' summary.

MOSQUITOES ASSOCIATED WITH SYLVAN YELLOW FEVER NEAR ALMIRANTE, PANAMA. By H. Trapido and P. Galindo. Amer. Jour. trop. Med. Hyg. 6(1):114–144. 1957. 21 refs. An analysis has been made of the composition of the sylvan mosquito fauna of a well developed virgin tropical rain-forest in which yellow fever appeared in 1951. The results are based on two years of collecting mosquitoes attacking human baits on the ground and in the forest canopy, during the daylight and evening hours. The circumstances under which yellow fever occurred are given, and the climate and microclimate of the rain-forest summarized. It is shown that in true rain-forest the vertical stratification of the sylvan mosquito fauna is much more pronounced than in open deciduous forest. The daily activity cycles of 19 species are illustrated, and an analysis made of the regularity of attack in the case of five species known or suspected as sylvan yellow fever vectors. In addition the annual abundance cycles of 19 species are given.—Authors' summary.

NOTICE OF FILM RELEASE

AN INTRODUCTION TO ARTHROPOD-BORNE ENCEPHALITIS M–237

16mm motion picture—color, sound.

17½ minutes, 629 feet, 1957.

Audience: Epidemiologists, sanitary engineers, insect and rodent control personnel and medical students.

Summary: Establishes the nature, significance, distribution extent, and known control measures for arthropod-borne encephalitis by: (1) an introduction to the disease—its definition and importance; (2) showing example cases in humans and horses; (3) the distribution of 3 types of arthropod-borne encephalitis and (4) both temporary and permanent control measures.

Available

On *Short-term loan* from: Chief, Communicable Disease Center, Public Health Service, Department of Health, Education, and Welfare, P. O. Box 185, Chamblee, Georgia.

For *Purchase,* from: United World Films, Inc., 1445 Park Avenue, New York 29, New York.

REFERENCES TO LITERATURE OF INTEREST TO MOSQUITO WORKERS AND MALARIOLOGISTS

HELEN SOLLERS

Plant Pest Control Division, Agricultural Research Service, United States Department of Agriculture

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